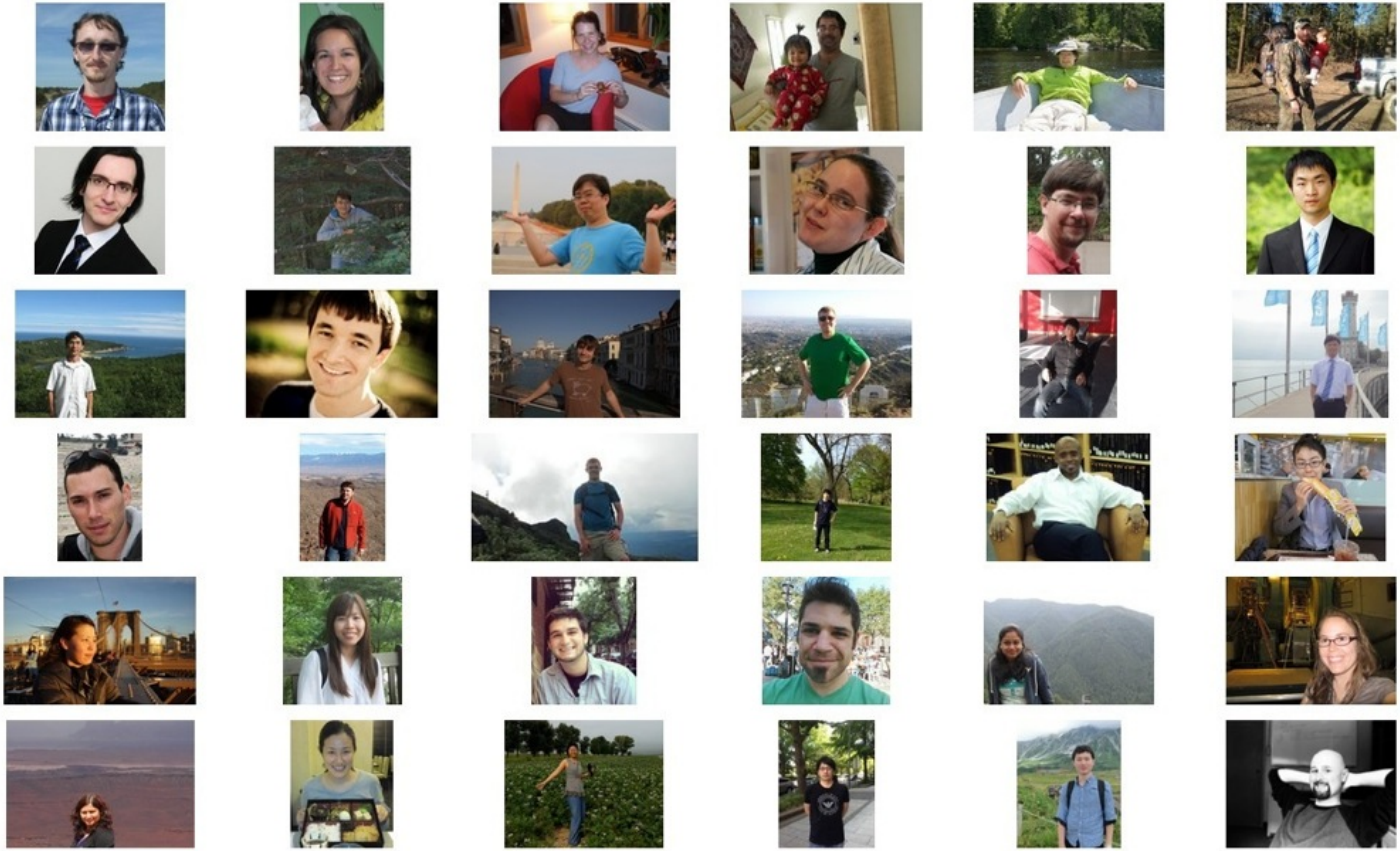
PHENIX Physics, Status, and Plans

Dave Morrison (BNL)
Jamie Nagle (Colorado)

Co-spokespersons

Collaboration membership, authorship

- 580 collaborators, 75 institutions, 15 countries
- updated our approach to determining “member in good standing” (MGS) for authorship for publications
  - individual collaborator response to MGS survey
  - scope of current work, desire to be considered MGS, contact info, affiliations, speaking topics
- author list for new publications =
  MGS lists for years in which relevant data were taken + MGS list for current year +
  spokespersons’ exceptions based on contributions
- regularizes inclusion of more recent collaborators, post-docs
- provides way to correct oversights and update information



Highlighting young scientists in the collaboration: every month we ask two young collaborators to tell us how they came to be in PHENIX, what their interests are, and to provide a picture.

PHENIX Collaboration Management

- Co-spokespersons:
  Jamie Nagle (Colorado), Dave Morrison (BNL)

- Deputy spokespersons:
  John Lajoie (ISU), Yasuyuki Akiba (RIKEN)

- Director of operations: Mickey Chiu (BNL)

- Run-15 coordinator: Doug Fields (UNM)

- Run-15 spin coordinator: Itaru Nagagawa (RIKEN)

Publications and data archiving

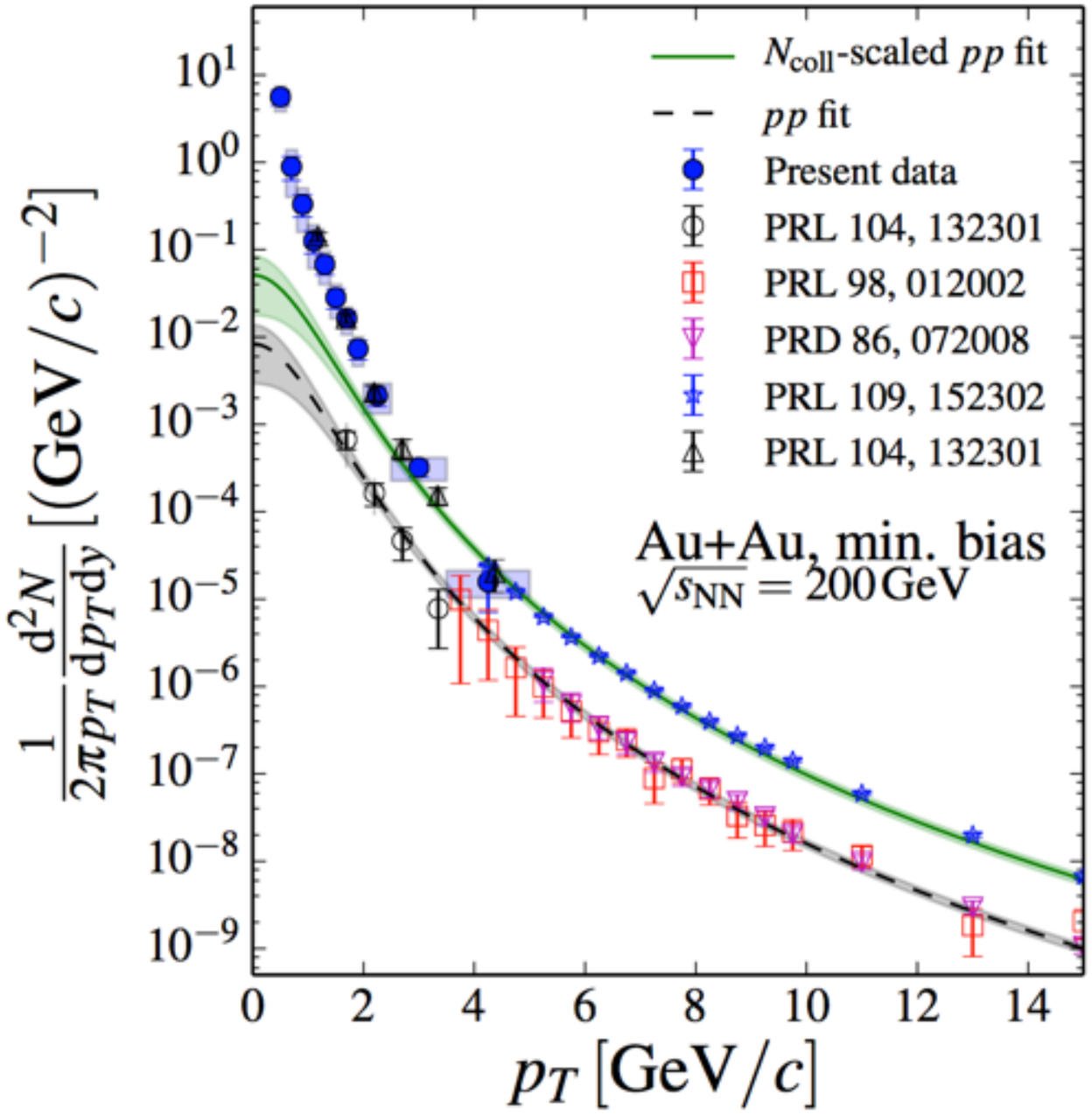
- As part of preliminary data approval, strengthened emphasis on an articulated path to publication

- PHENIX has submitted 24 manuscripts for publication over the last 12 months – a record for the collaboration!

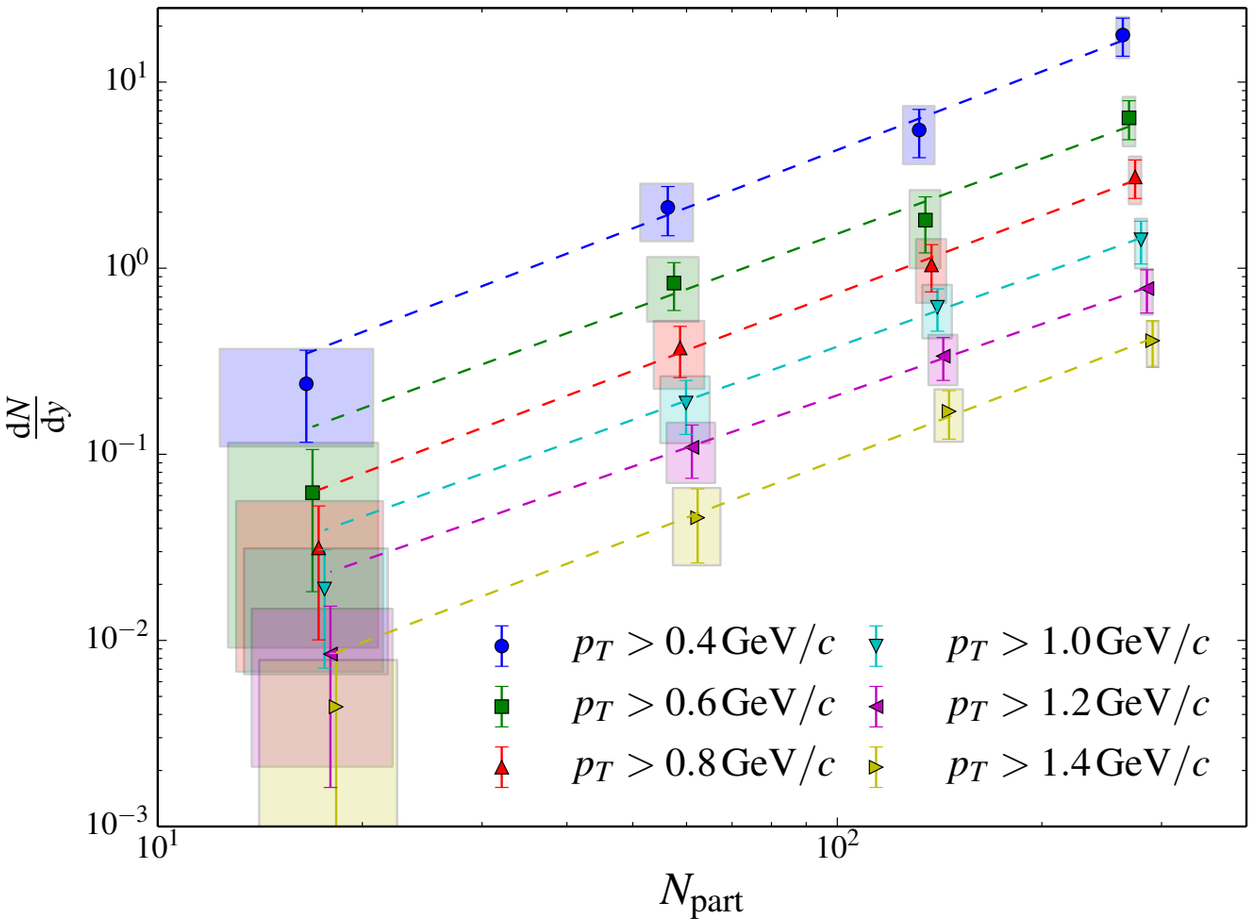
- Comment at last review that PHENIX should archive final data values by uploading to HepData (we already required final data as locally hosted text files) – we now have final data for 25 publications uploaded to HepData.

Large direct photon yield, extension to lower p_T and centrality dependence

Based on external conversion in detector material
able to go to much lower p_T ~ 400 MeV/c



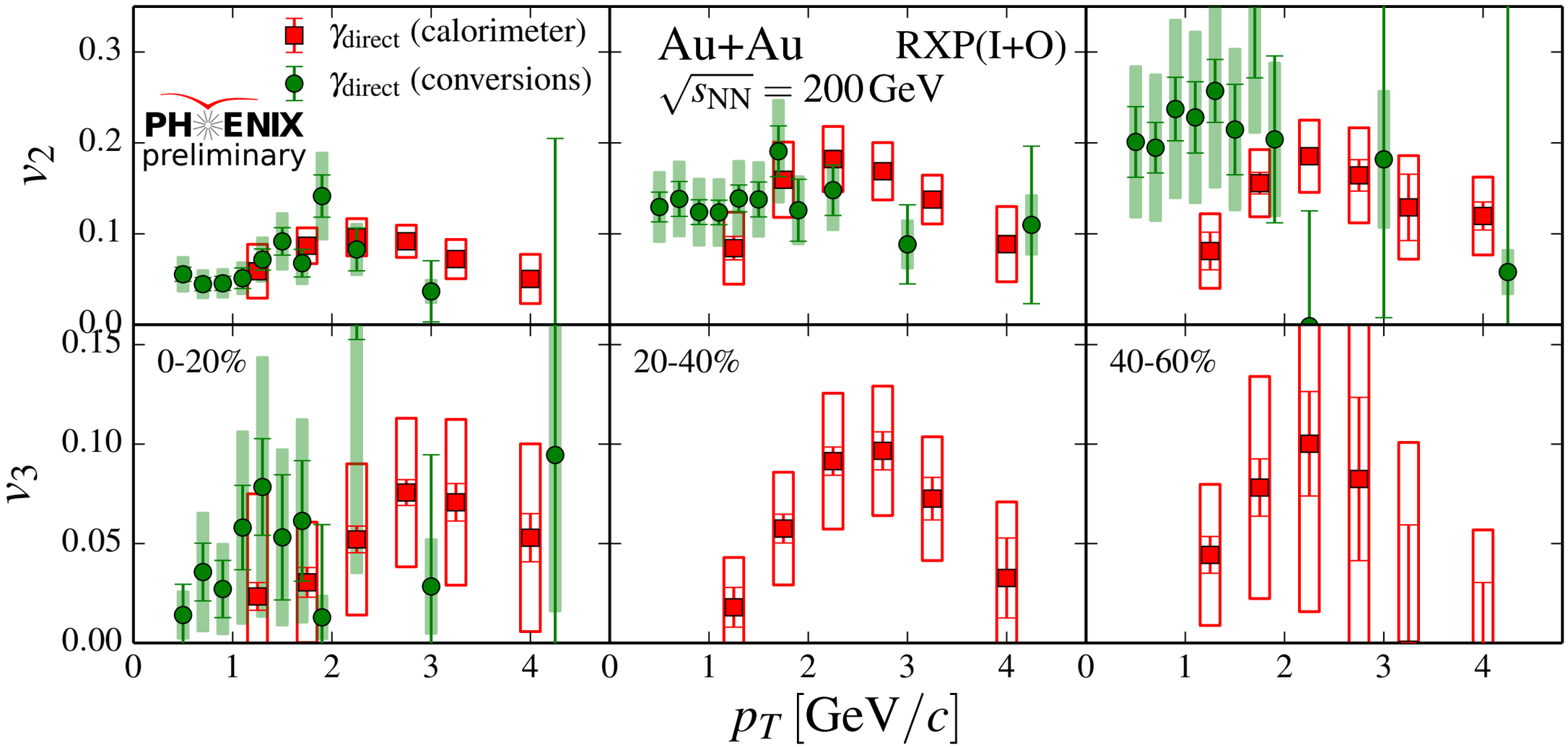
Very differential – able to map out
centrality and p_T dependence in detail



arXiv:1405.3940

Azimuthal anisotropy of direct photon production

Analysis technique using real photon conversions. Results are very consistent with the previously published PHENIX results using internal conversions of virtual photons.



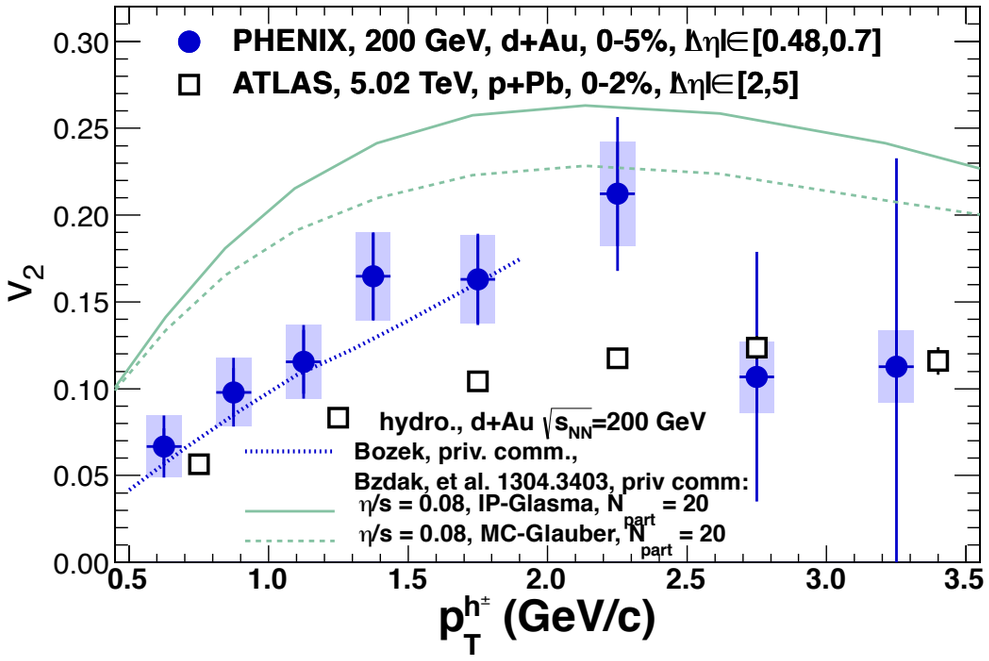
Continues to be tension between large direct photon yields (preferring early emission) and large v_2 (preferring late emission). Direct photon v_3 adds distinguishing power.

First measurement of direct photon v_3

Longer range azimuthal correlations in d+Au

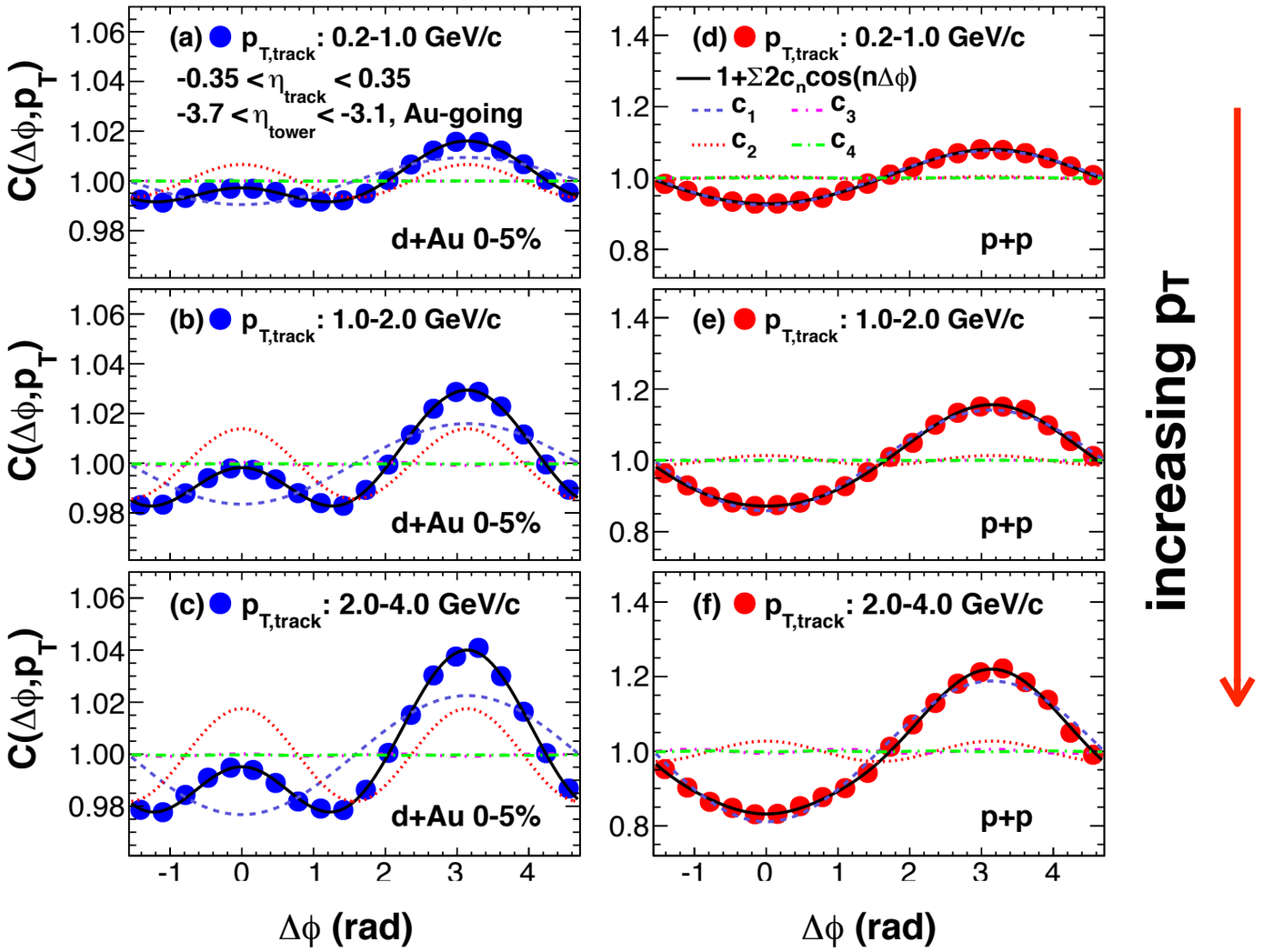
Following on publication of two-particle correlation measurements in d+Au (Phys. Rev. Lett. 111, 212301 – Published 20 November 2013), use muon piston calorimeter (MPC) for longer range correlations to minimize jet-like autocorrelations.

Δη ~ 0.7



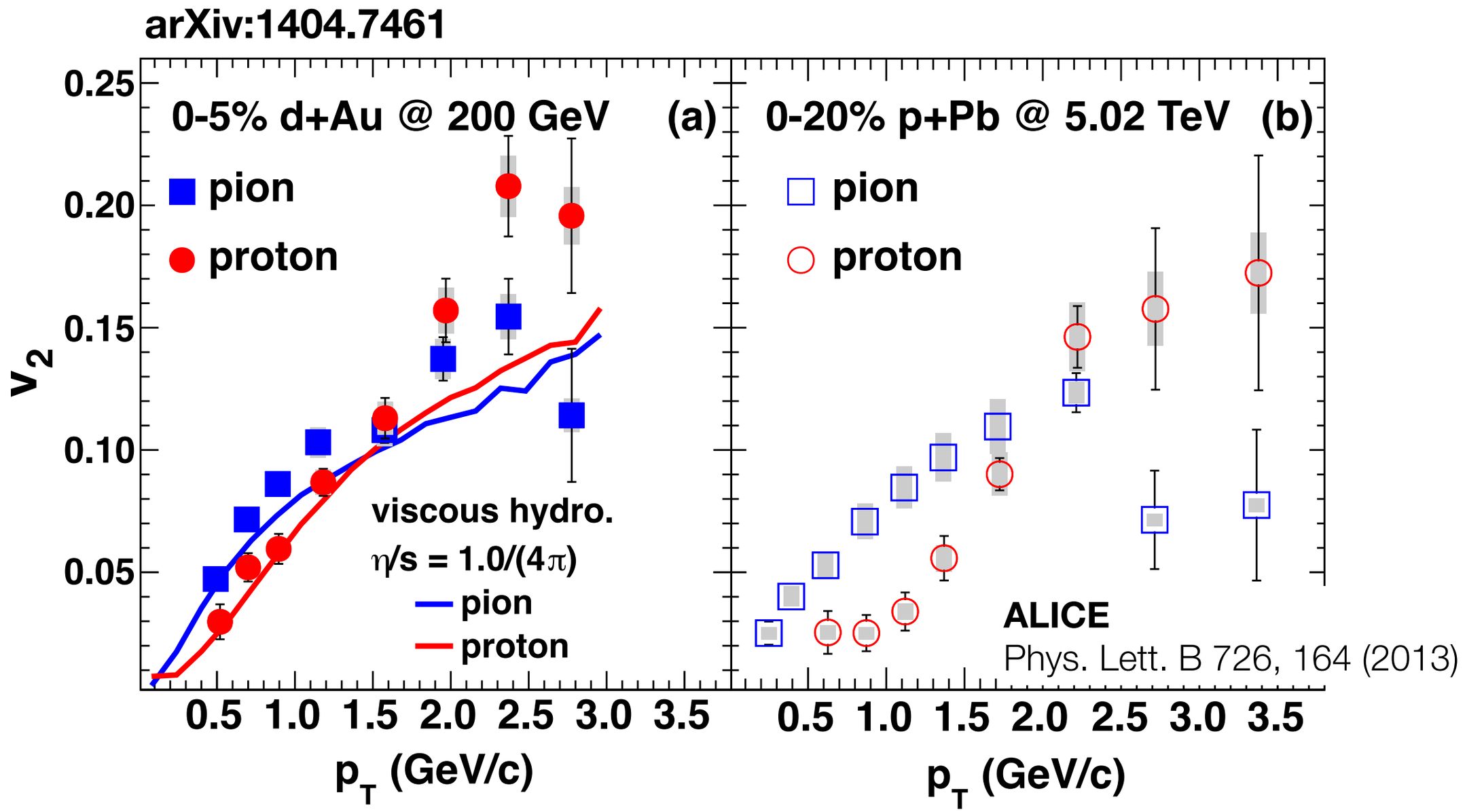
Phys. Rev. Lett. 111, 212301

Δη ~ 3



arXiv:1404.7461

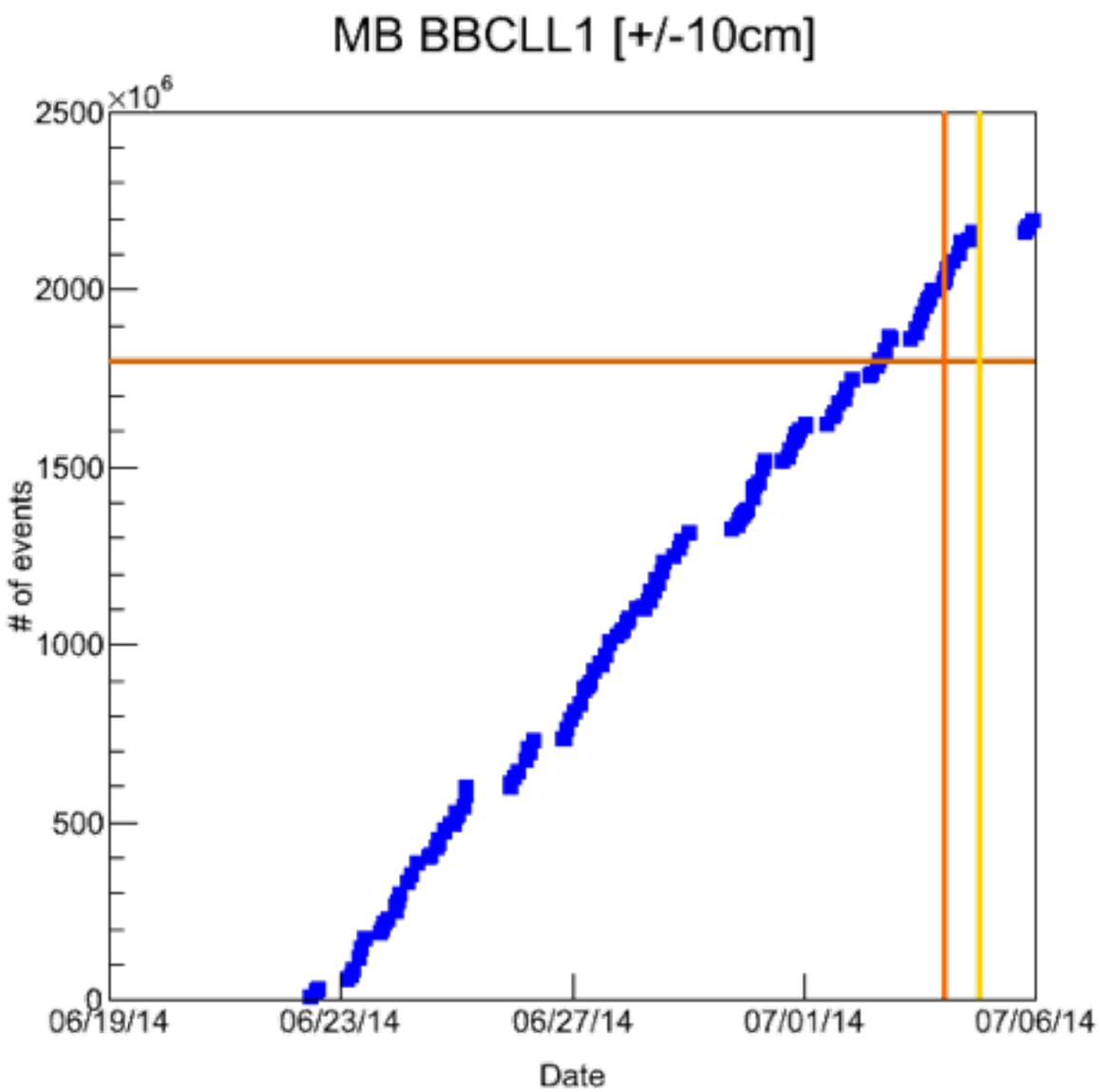
Mass ordering as further indication of d+Au flow



Mass ordering ($p_T < 2$ GeV/c) of the v_2 of identified charged particle is observed.

Would be expected if all particles – light and heavy – flow with a common velocity.

Geometry control: ^{3}He+Au investigates small QGP



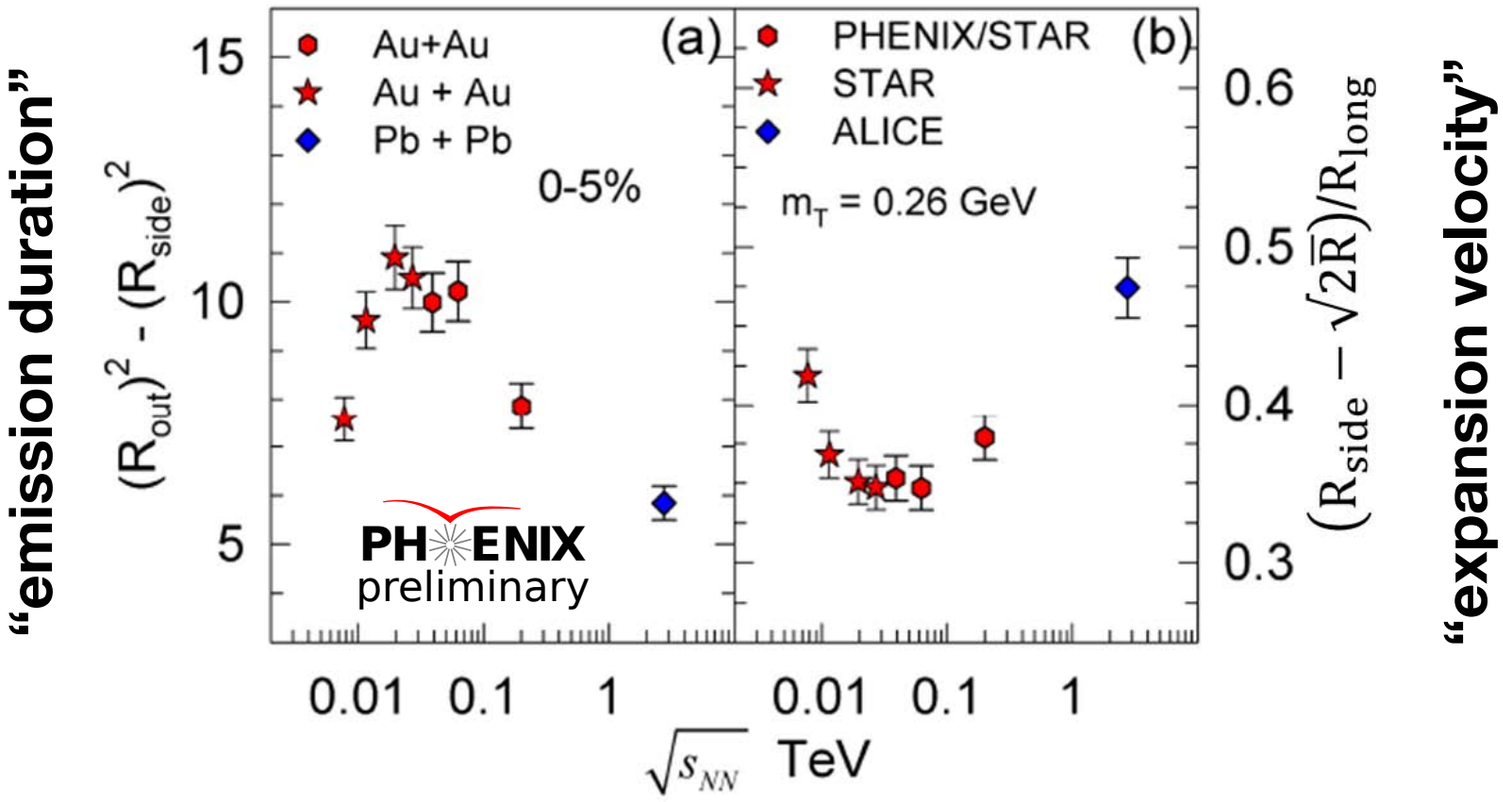
Further investigation of QGP in small systems through collisions with intrinsic ε_3

Possible because of great success of Au+Au in Run-14 and RHIC flexibility

Recorded 2.2B minimum bias events; also centrality trigger on top 4% of beam-beam counter response.

Rapid production pass and early look at data indicate non-zero v_3

System size and √s dependence of HBT parameters

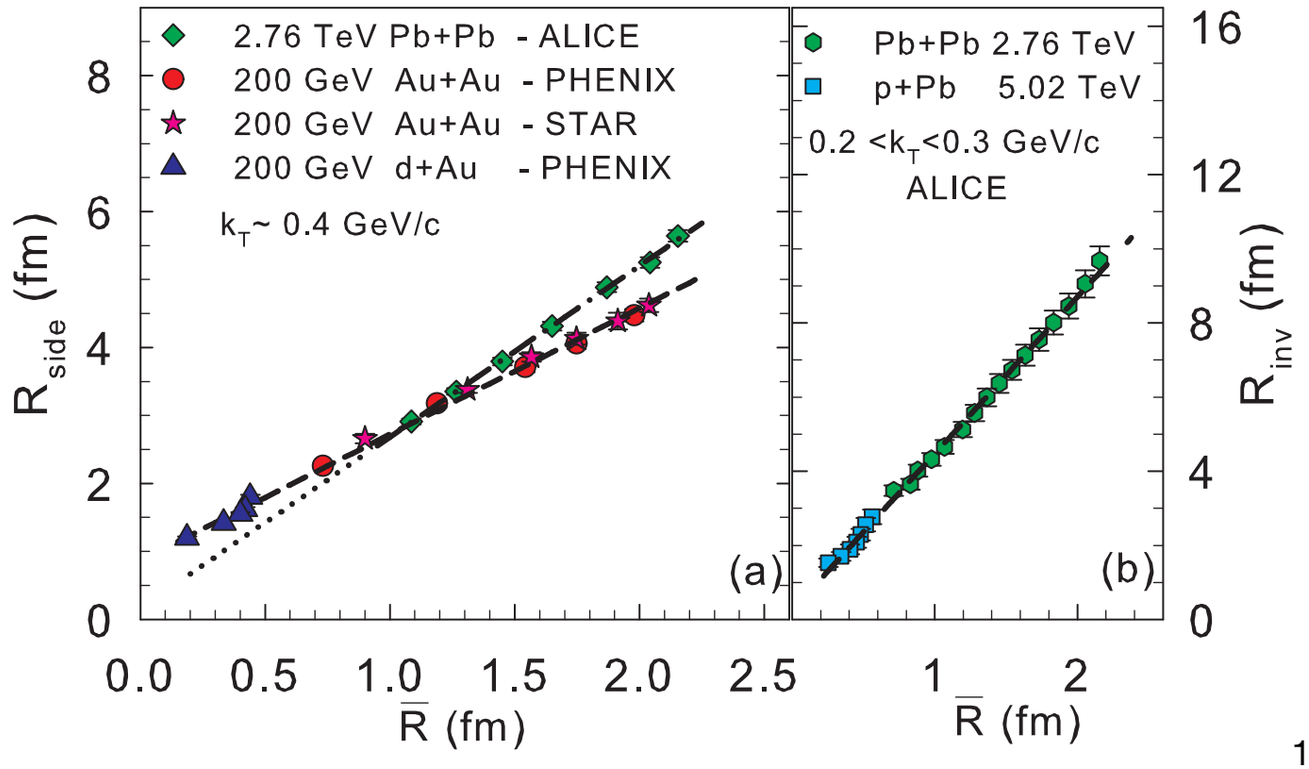


Around $\sqrt{s_{NN}}$ ~ 30 GeV see maximum of emission duration and minimum of expansion velocity, behavior one would expect near first order phase transition

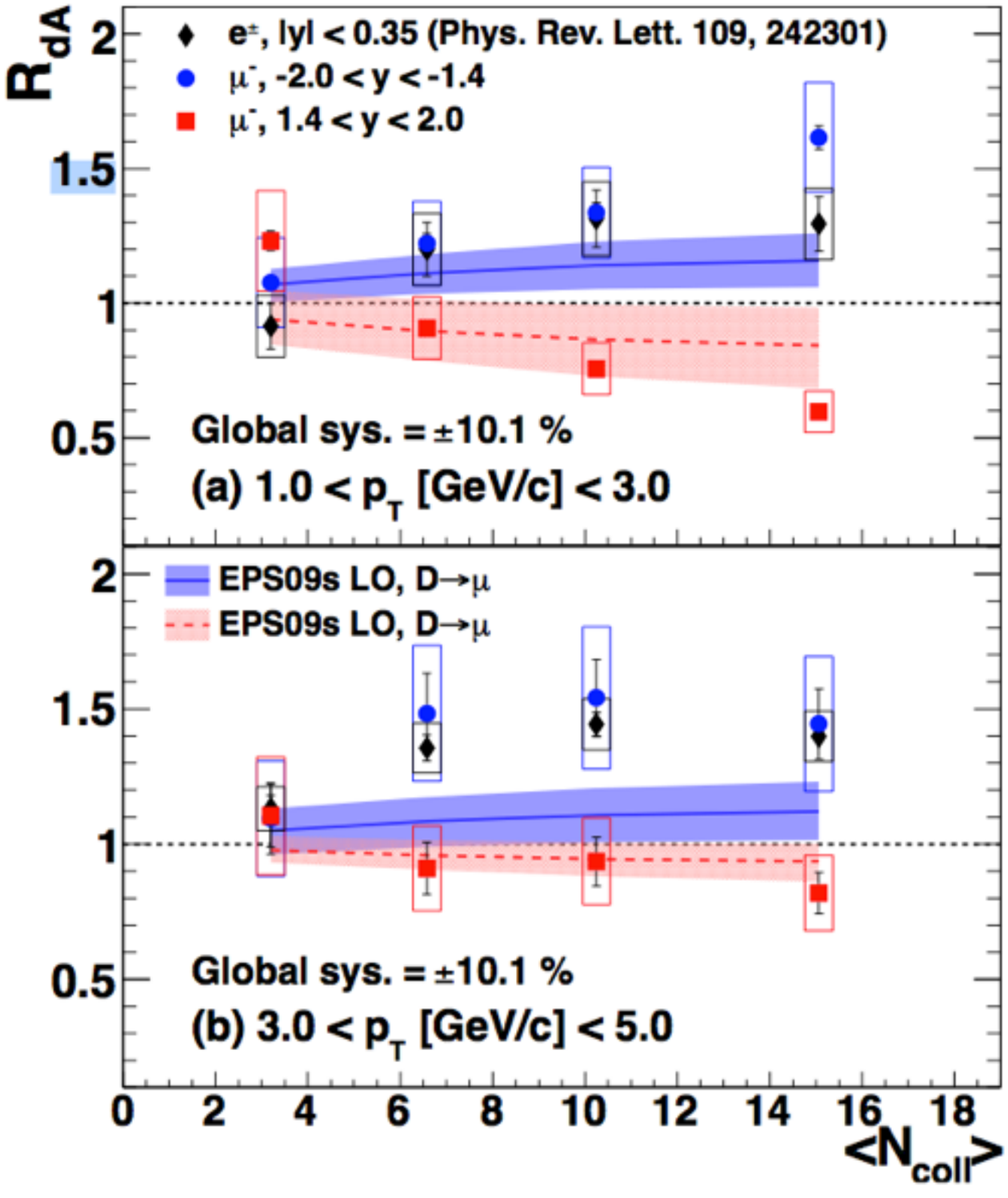
$$1/\overline{R} = \sqrt{\left(1/\sigma_x^2 + 1/\sigma_y^2\right)}$$

$\overline{R}$ dominated by the smaller extent in coordinate space – compatible with pressure gradient driven expansion

arXiv:1404.5291



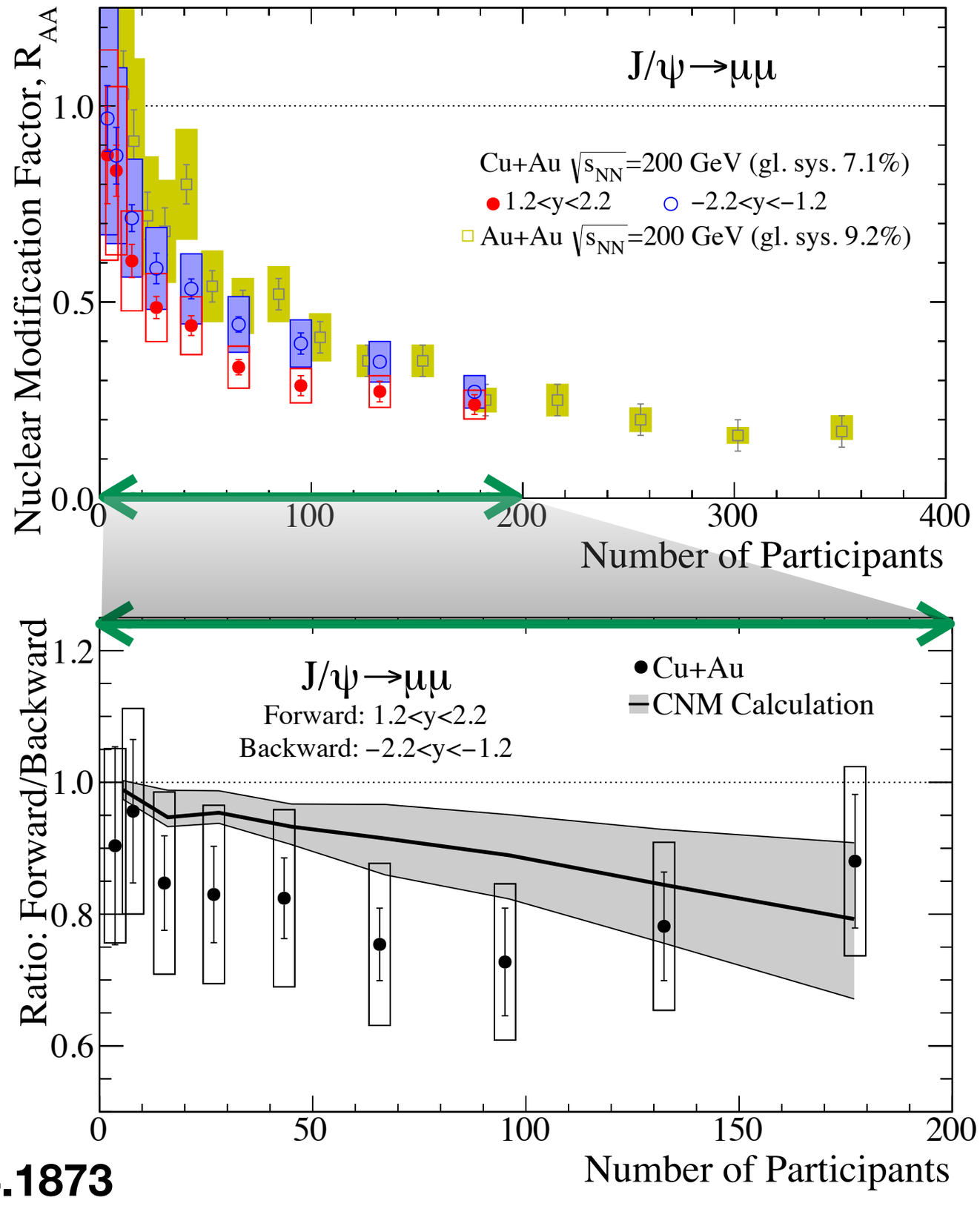
Heavy Flavor Single Muon R_{dAu}



Enhanced single lepton yield in the central and backward rapidity (i.e. Au-going direction).

One possible explanation is heavy flavor flow

J/ψ R_{AA} in the asymmetric system Cu+Au

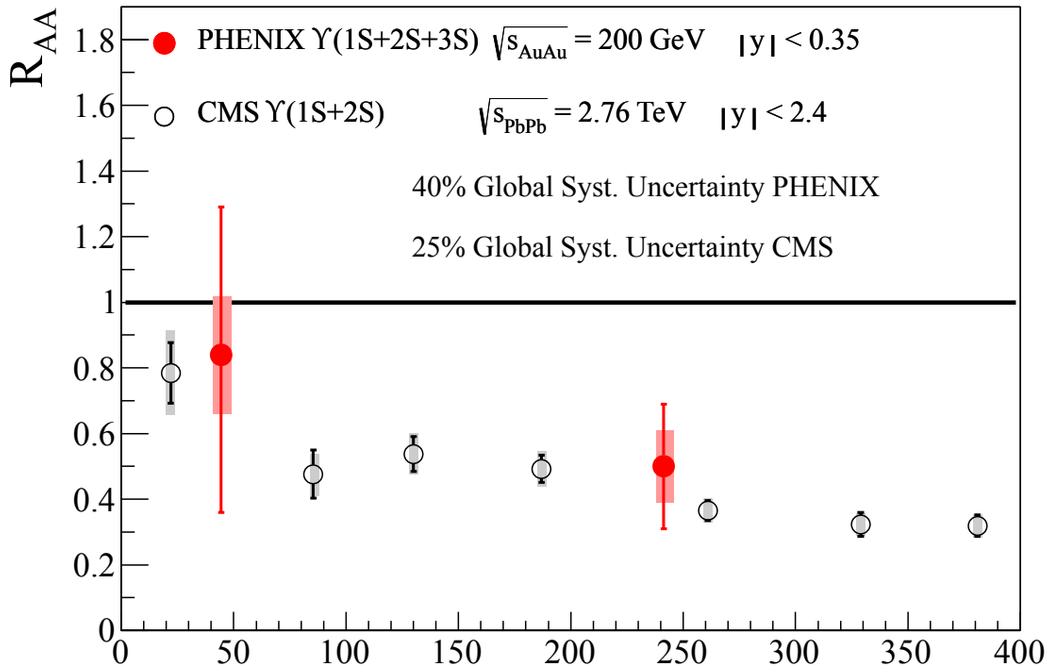


Provides additional handle for investigating medium dependence.

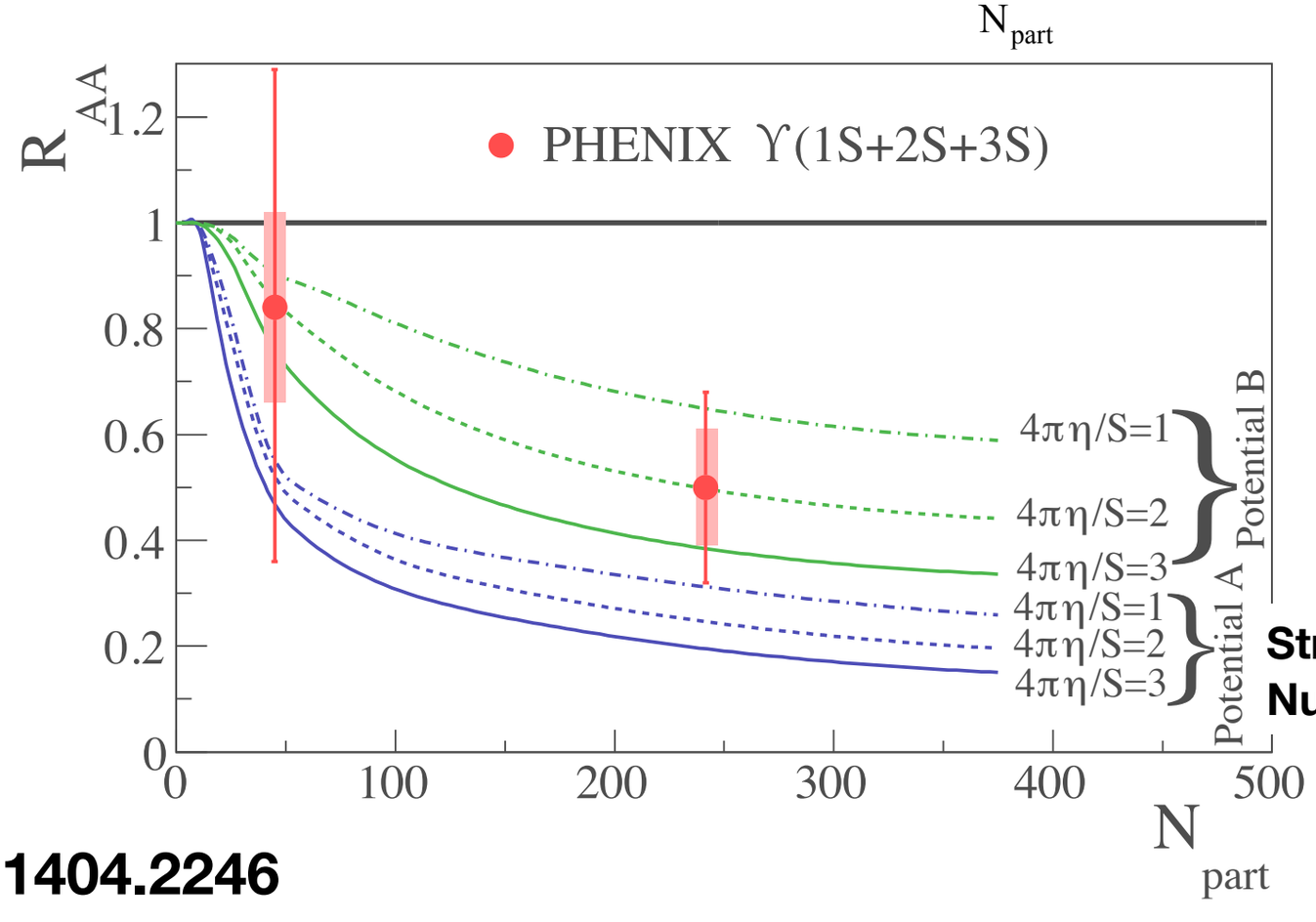
While the forward/backward R_{AA} ratio is compatible with EPS09 nuclear modified PDFs, there is room to accommodate additional cold nuclear matter effects.

arXiv:1404.1873

PHENIX Upsilon Results in Au+Au



Substantial upsilon suppression in central events. PHENIX result is compatible with CMS result. Consistent with total disappearance of Y(3S).



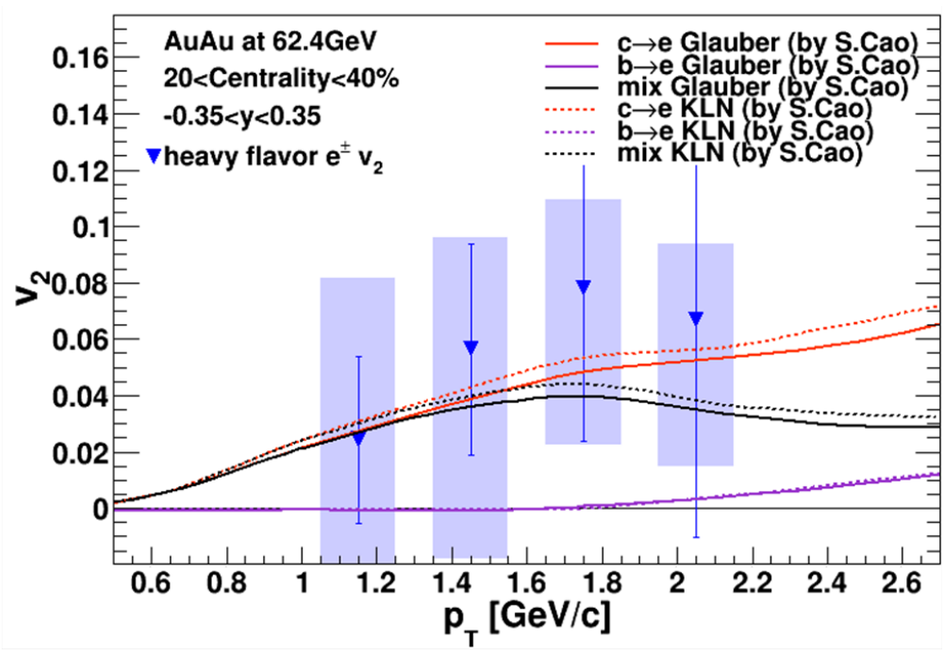
High statistics, high resolution upsilon measurement with ability to separate mass states is a cornerstone of sPHENIX physics program.

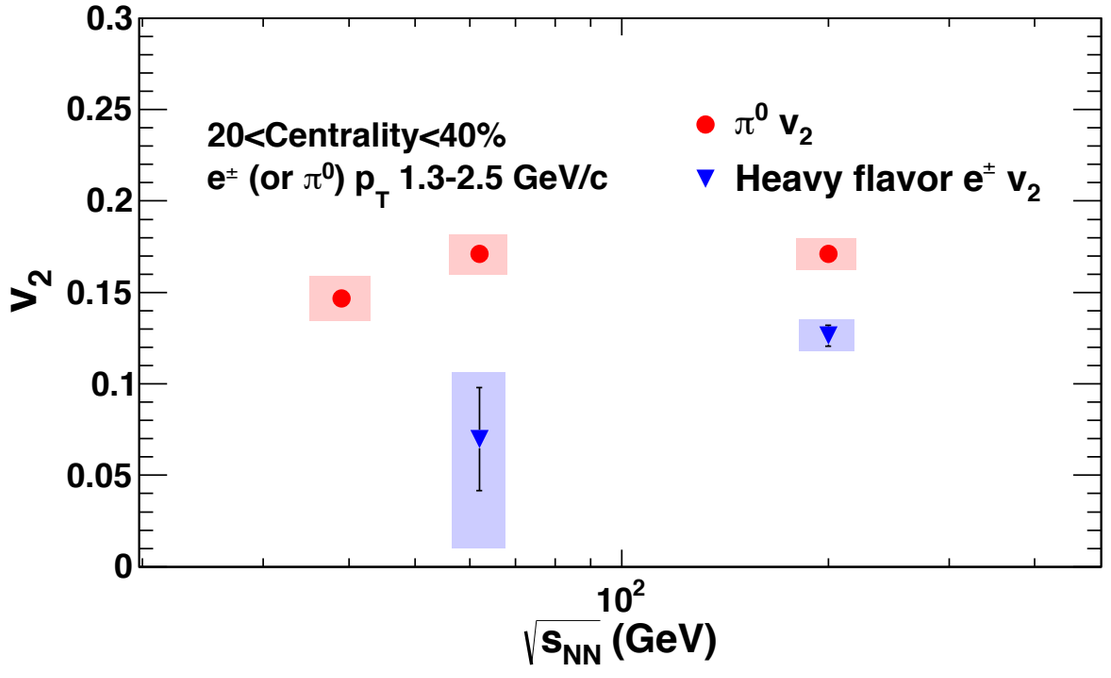
Strickland and Bazow
Nucl. Phys. A 879, 25 (2012)

arXiv.1404.2246

Heavy quark flow in Au+Au at $\sqrt{s_{NN}}$ = 62.4 GeV

arXiv:1405.3301





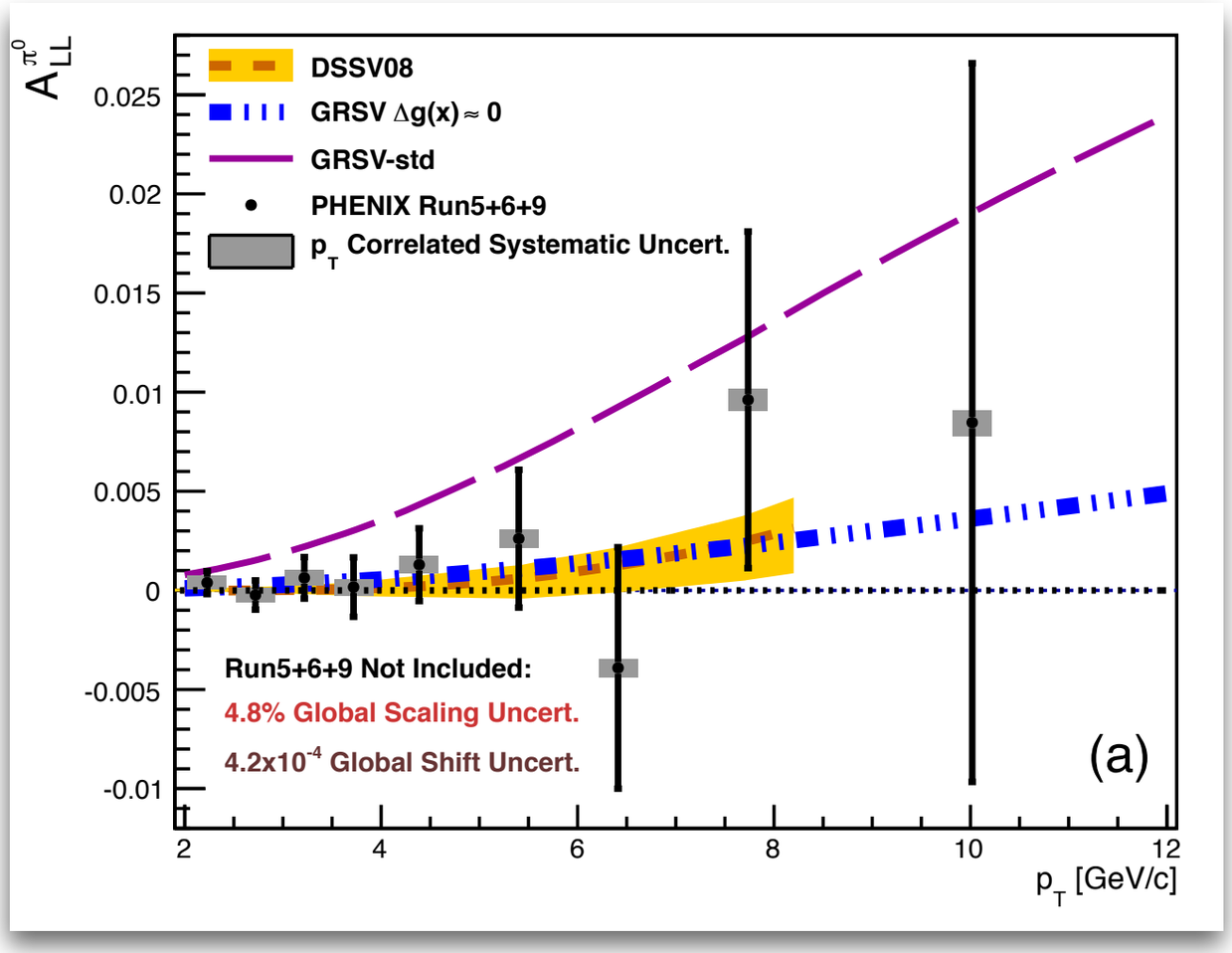
Closer to T_C, potentially more strongly coupled system, heavy quark flow.

Basis for PHENIX interest in Au+Au and *p*+*p* at $\sqrt{s_{NN}}$ = 62.4 GeV – now that silicon vertex detectors are installed and operating excellently.

Related interest in direct photon yield and v_2 and dilepton yield at $\sqrt{s_{NN}}$ = 62.4 GeV.

Recent PHENIX accomplishments in spin physics

Phys. Rev. D 90, 012007 – Published 17 July 2014

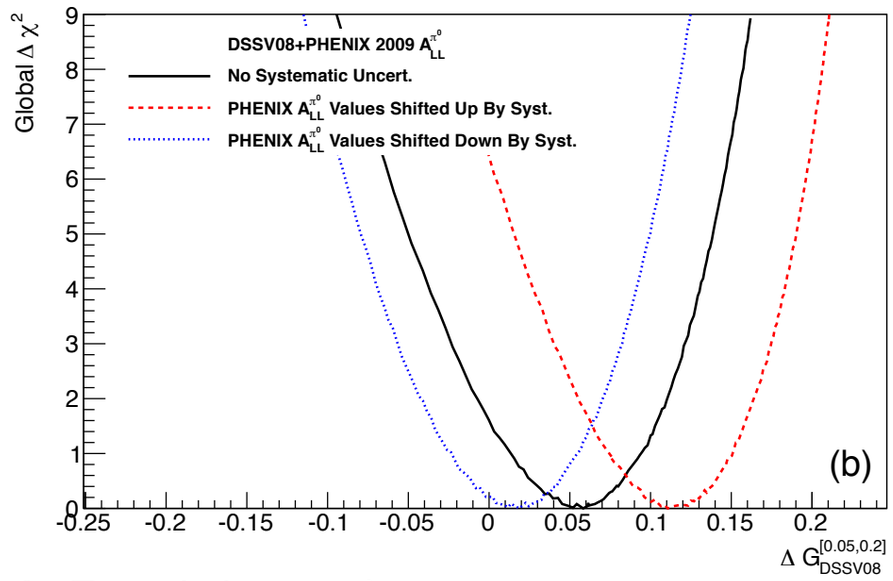


Evidence for Polarization of Gluons in the Proton

de Florian, Sassot, Stratmann, Vogelsang

Phys. Rev. Lett. 113, 012001 (2014)

…the key ingredients to our new QCD analysis are the 2009 STAR [6] and PHENIX [7] data on the double-spin asymmetries for inclusive jet and π^0 production.

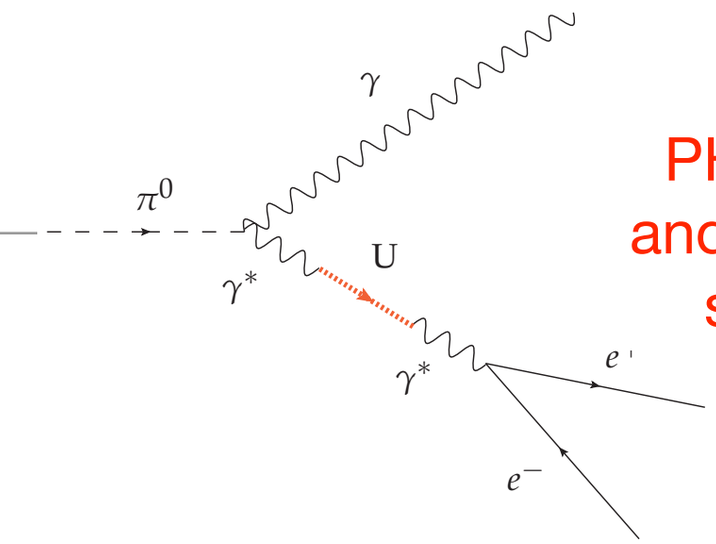


Recent very successful six week “spin fest” at UIUC (M. Perdekamp):

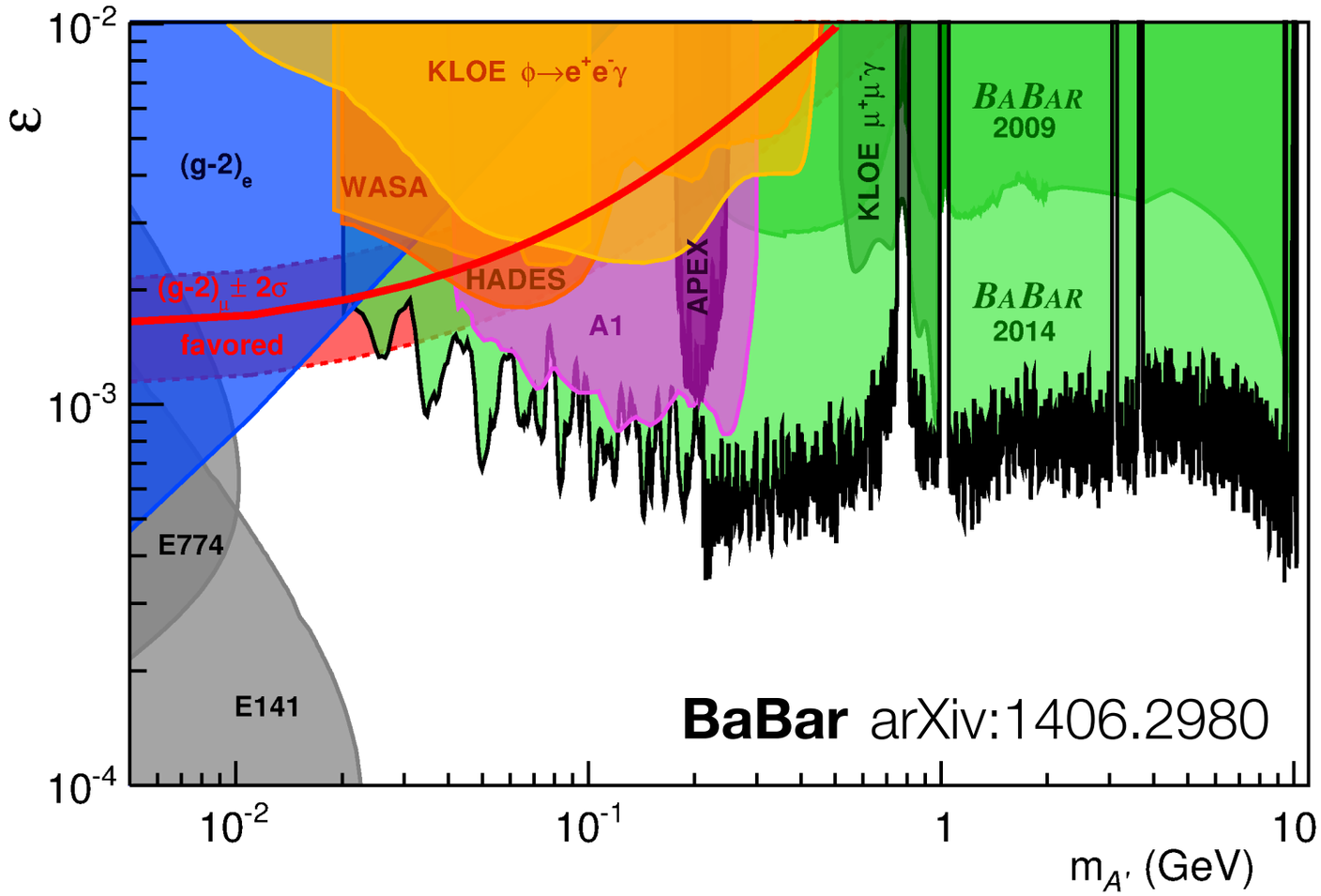
24 participants, lectures, work on analysis.

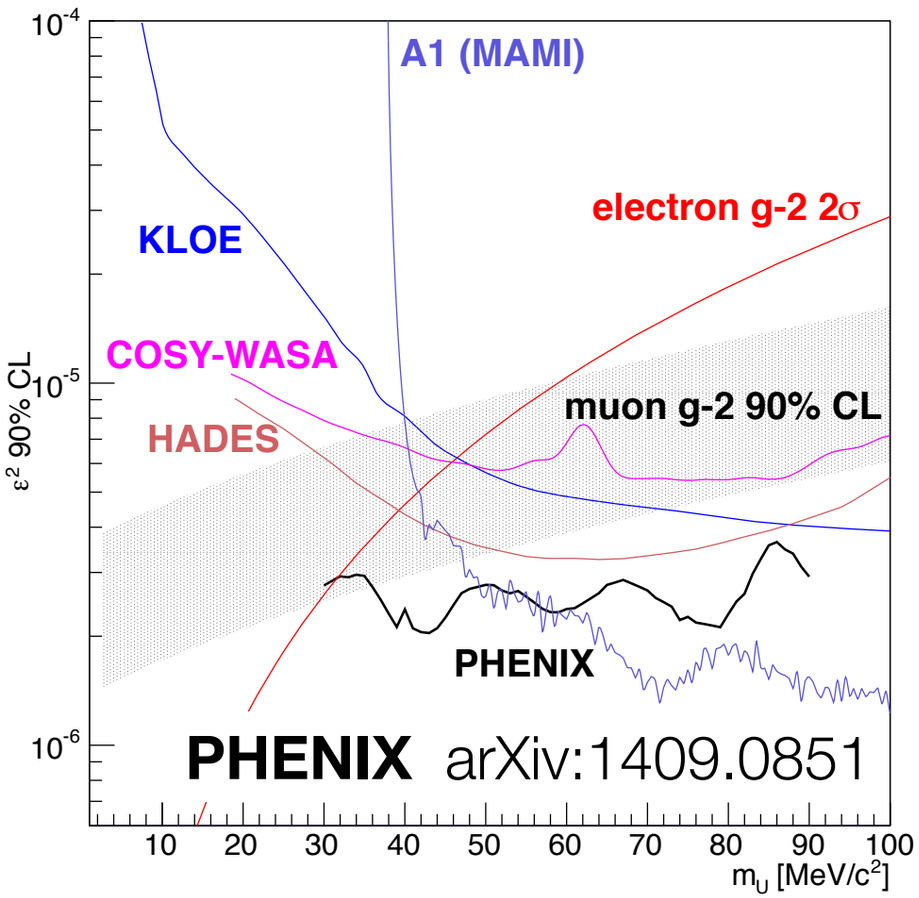
Worked with BNL public affairs (from PHENIX: J. Lajoie, K. Boyle) and STAR to produce BNL news story about spin – to be released soon.

Dark photons



PHENIX: excellent electron ID and e^+e^- mass resolution – huge sample of π^0 Dalitz decays

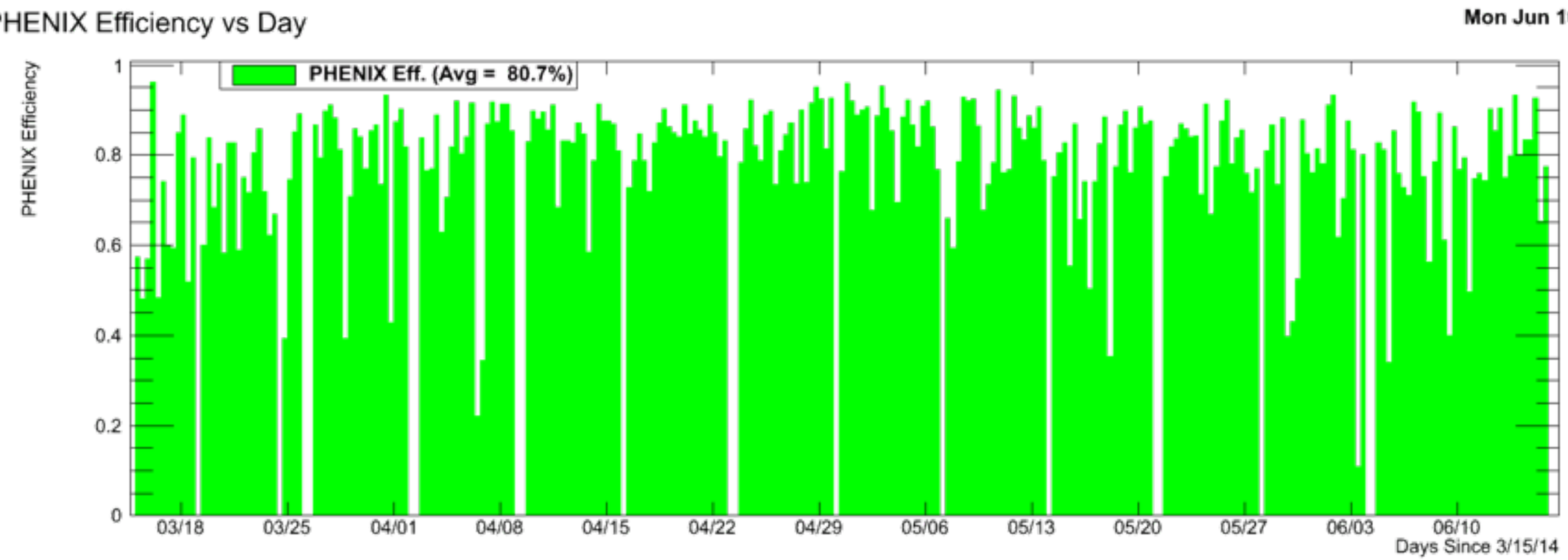




With recent combined limits, essentially all phase space for the dark photon as an explanation of the $(g\text{-}2)_\mu$ anomaly has been ruled out.

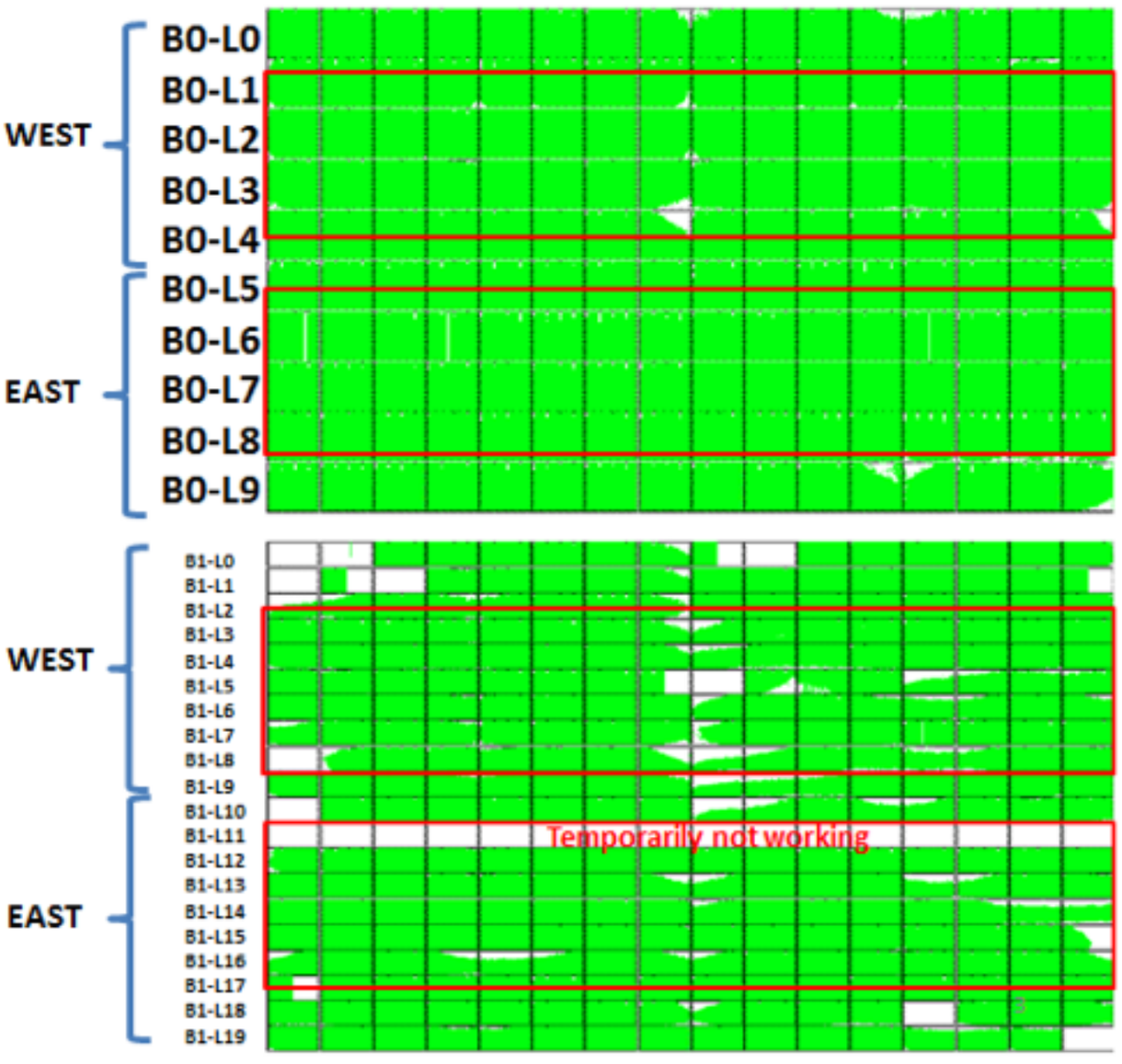
PHENIX during Run-14

At the last S&T review, data taking efficiency was ~70%. Repeatable stores, steady C-AD operation, longer PHENIX runs, and dedicated attention to operations has raised this to >80%.

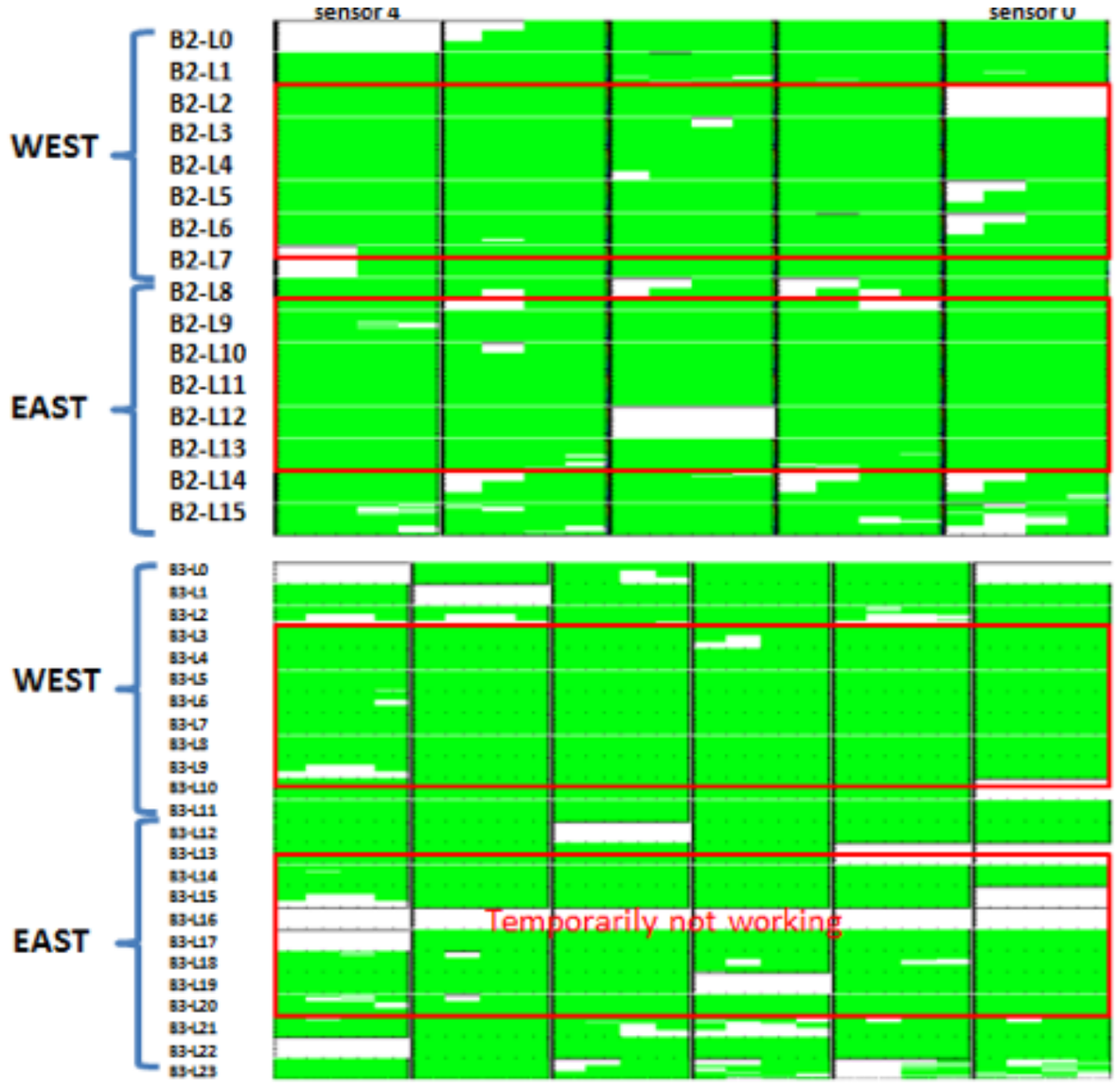


VTX performed very stably during Run-14

Pixel live area

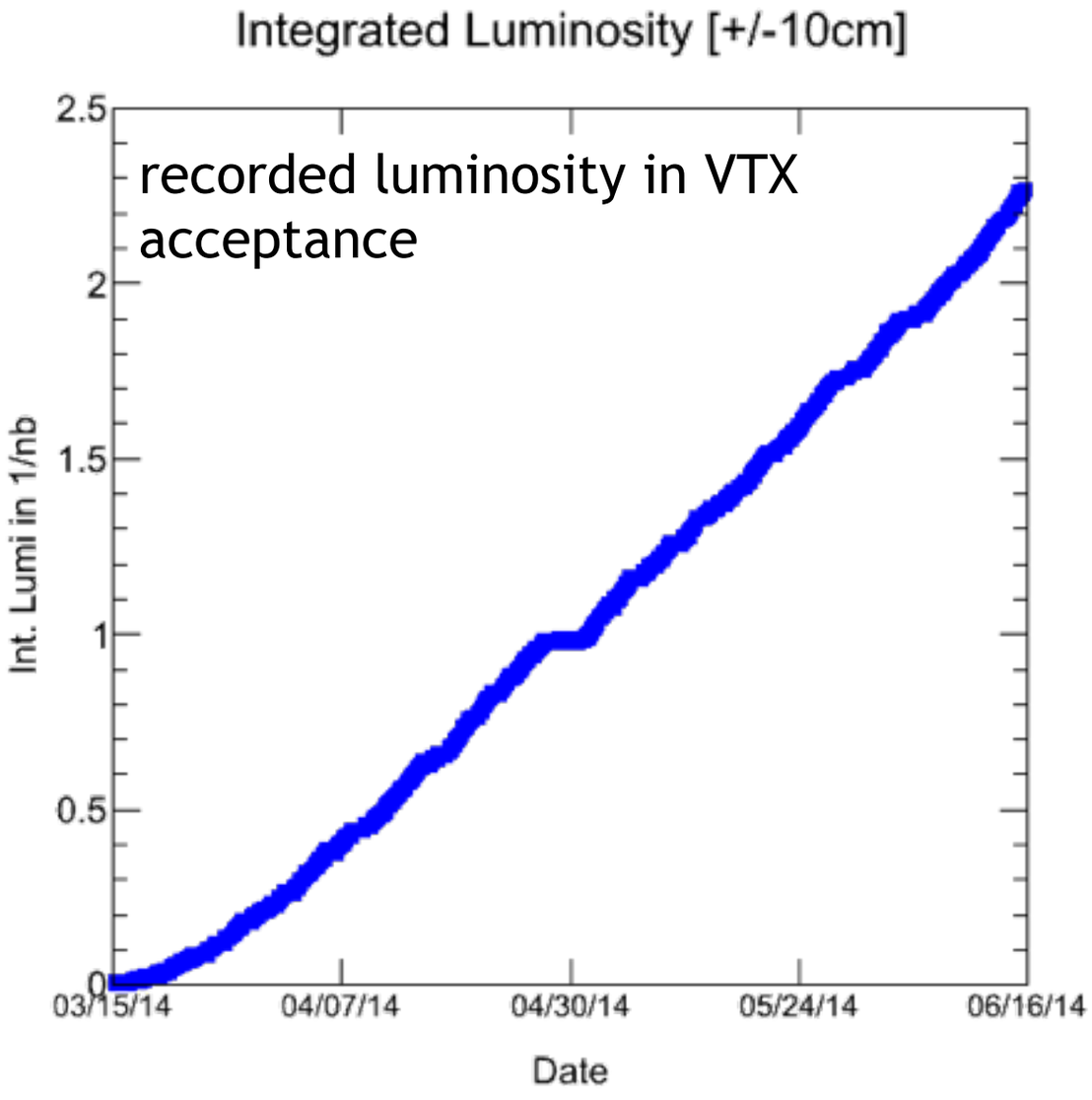


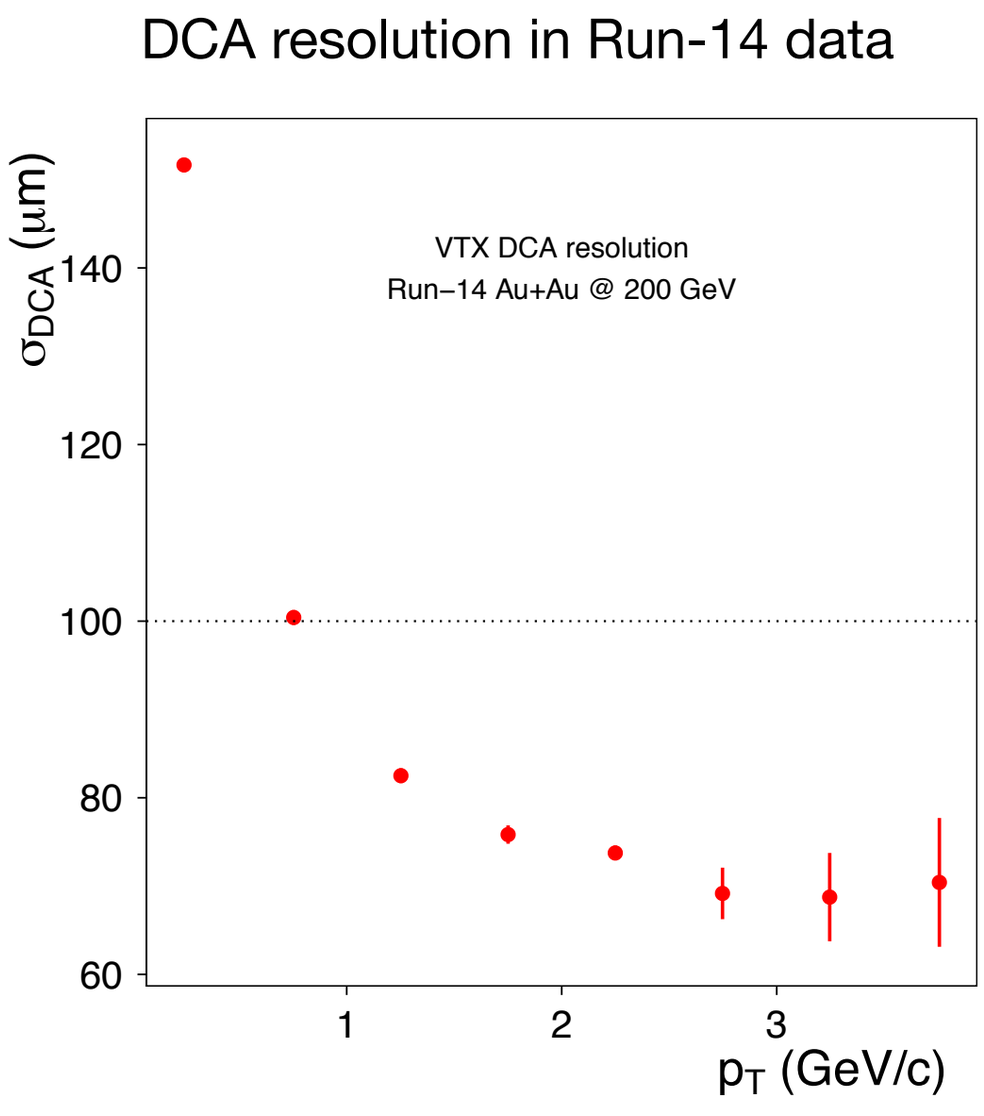
StriPixel live area



- VTX is in its best running condition
- Live area in CM acceptance: B0:98% B1:83% B2: 95% B3: 84%

Run-14: focus on heavy flavor



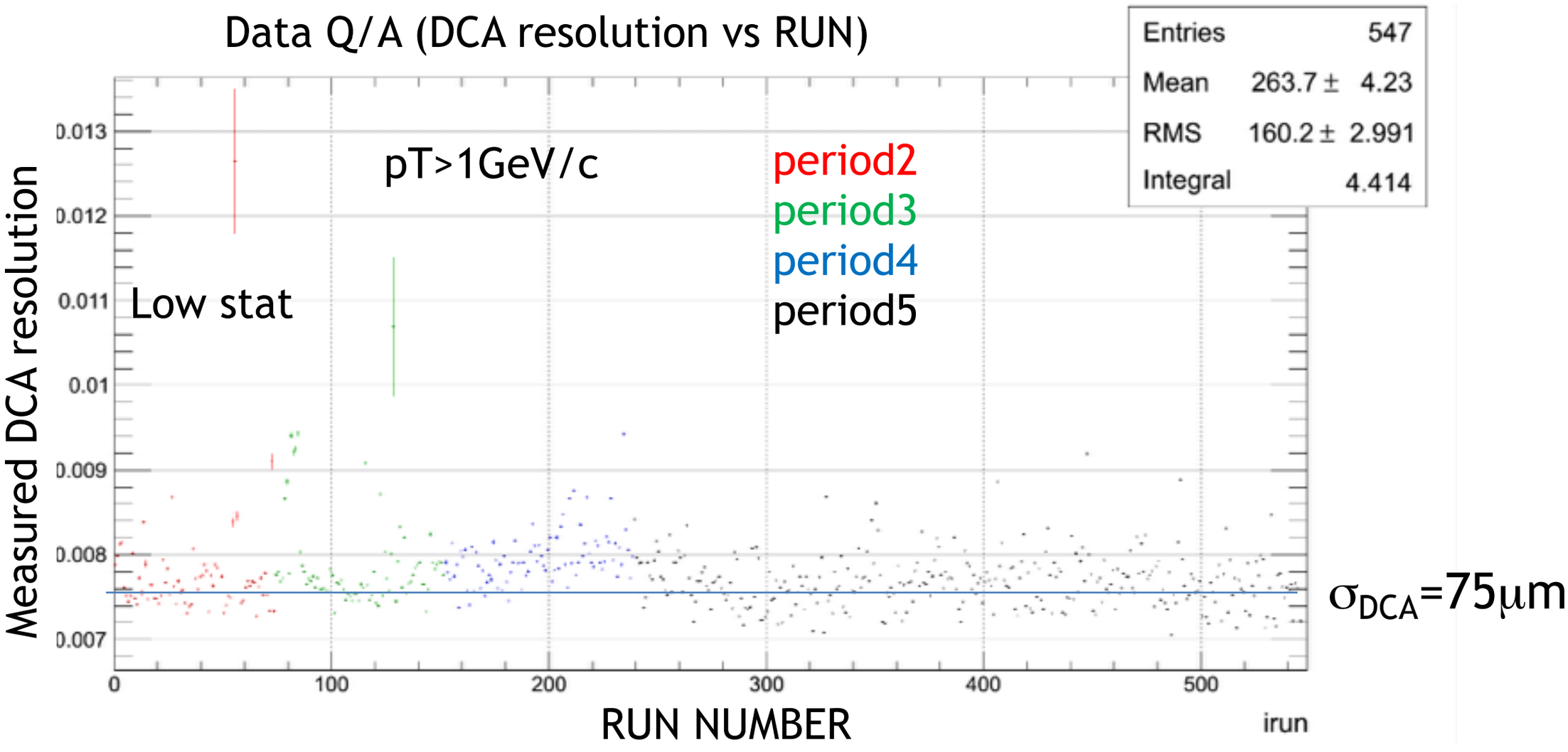


2.3/nb or 14.3 B Au+Au events **recorded** within |z|<10cm (good VTX acceptance)

Total # of events recorded > 17 Bi

DCA resolution 80μm for $p_T > 1$ GeV achieved in Run-14. Will be improved by further refinement of alignment/calibration

Finalizing Run-11 analysis



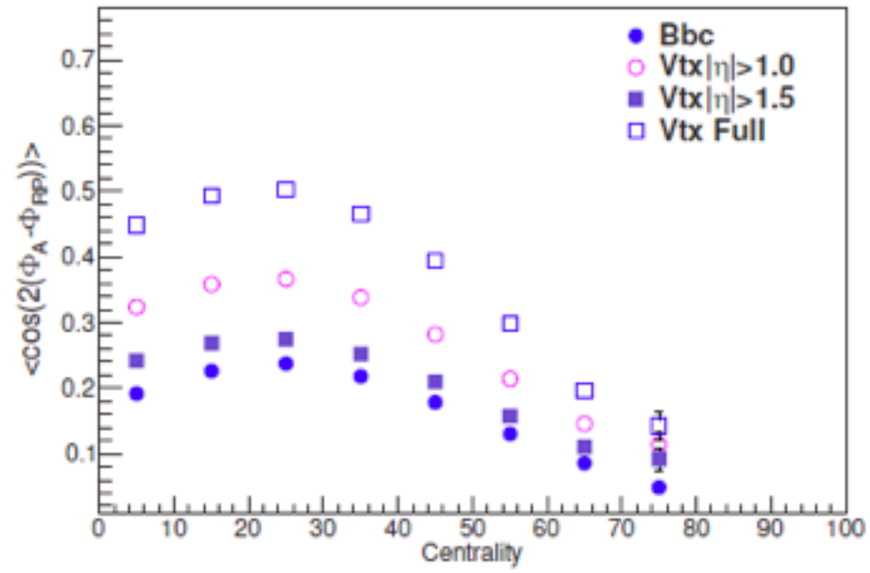
σ_{DCA}=75μm

- We are finalizing the Run-11 data analysis
- DST production has been re-done with better calibration and improved code
- ~2.8 billion events in VTX acceptance reconstructed
- Q/A check of the data on going
  - DCA resolution is stable (~75 micron for p_T>1GeV/c) during the run
- Final b→e/c→e measurement results by the end of the year

FVTX Physics Performance

Reaction Plane, Vertex : Currently provides best resolution RP in PHENIX, separates multiple vertices in 510 GeV p+p

Reaction Plane from FVTX, BBC



Vector Mesons:

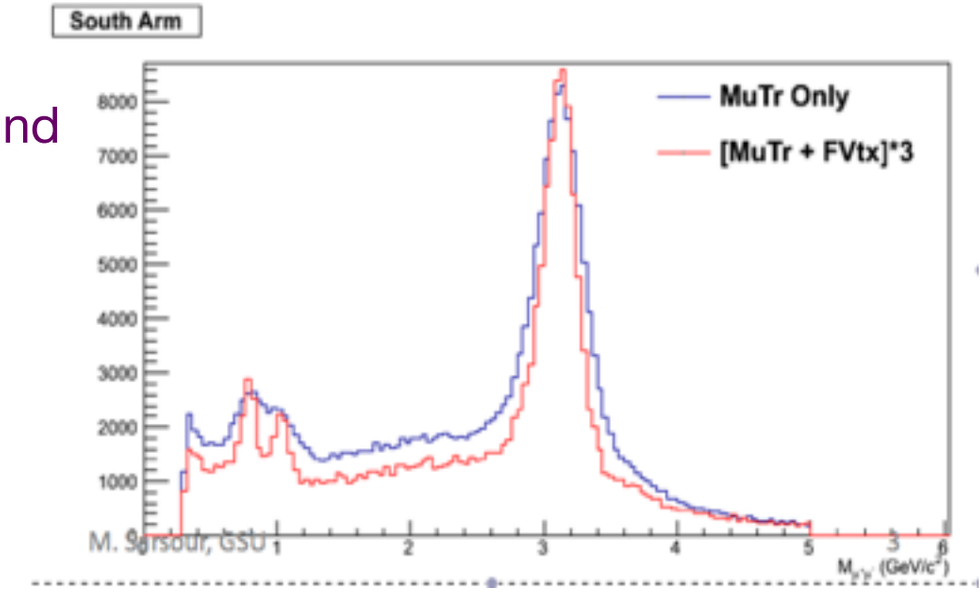
- Opening angle measurement improves mass resolution
- Rejection of hadronic backgrounds improves signal:backgrou

W Analysis:

- Potential to improve signal:background through background rejection (in progress)

Open Heavy Flavor:

- Rejection of hadronic backgrounds improves signal:background
- DCA measurements allows c, b separation
- Needed DCA resolution has been achieved



Drell-Yan:

- Rejection of hadronic backgrounds through track quality cuts
- Isolation cuts further discriminate DY from other dimuon backgrounds.

FVTX First Results

Reaction Plane and Flow

- FVTX used in CuAu analyses

J/ψ: ψ' ratio at forward rapidity

- First J/ψ:ψ' ratio at forward rapidity extracted
- J/ψ:ψ' ratio from CuAu in progress

Event Topology

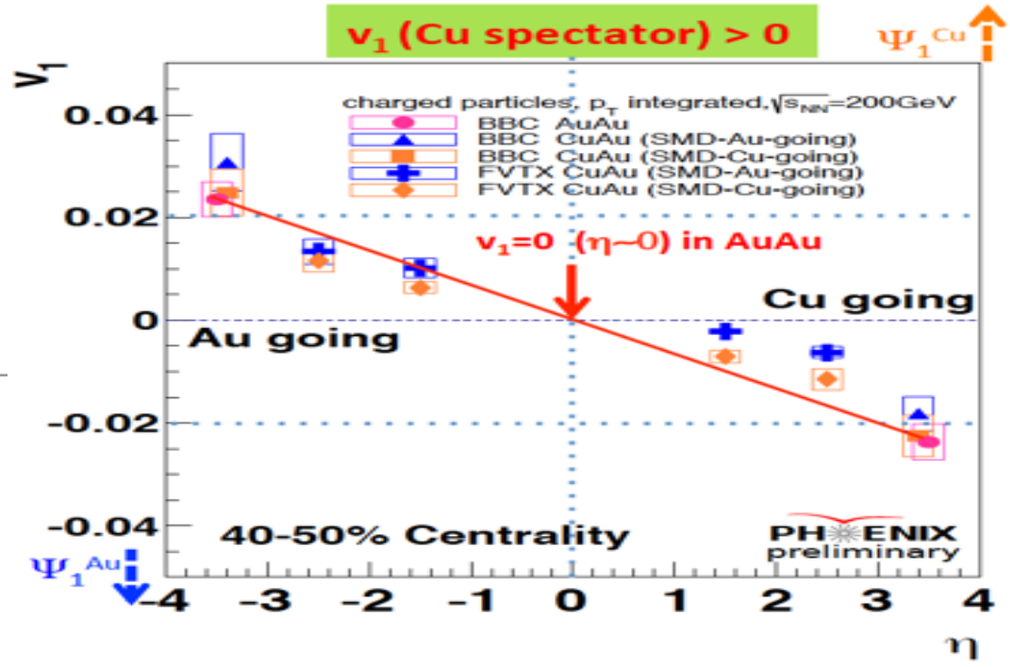
- J/ψ yield versus event topology can shed light on production mechanisms, analysis in progress

Open Heavy Flavor

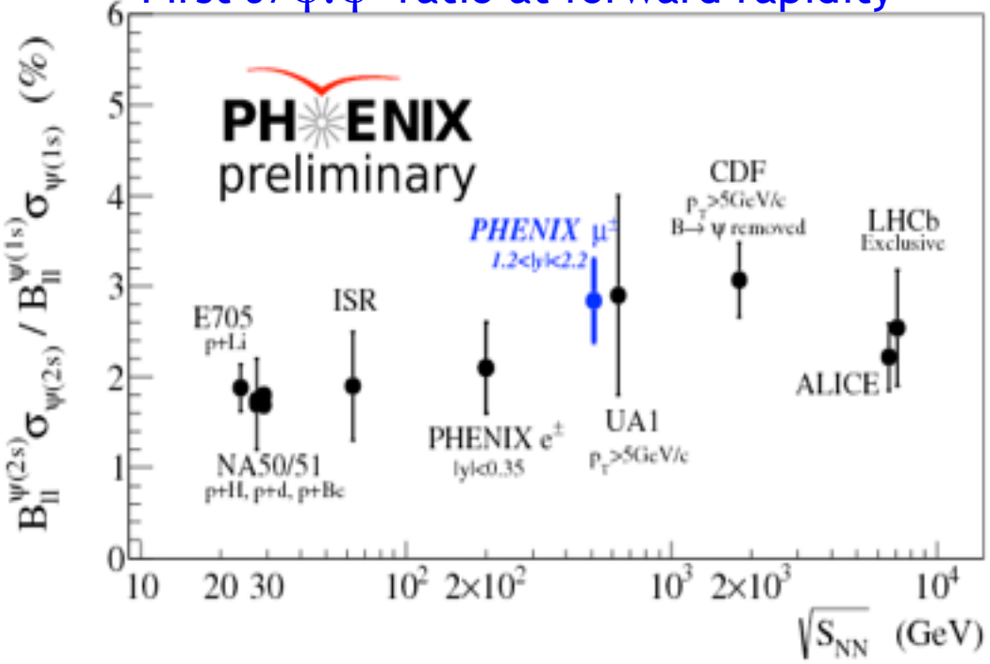
- Good DCA resolution now obtained. Proceeding on ful data productions and analysis

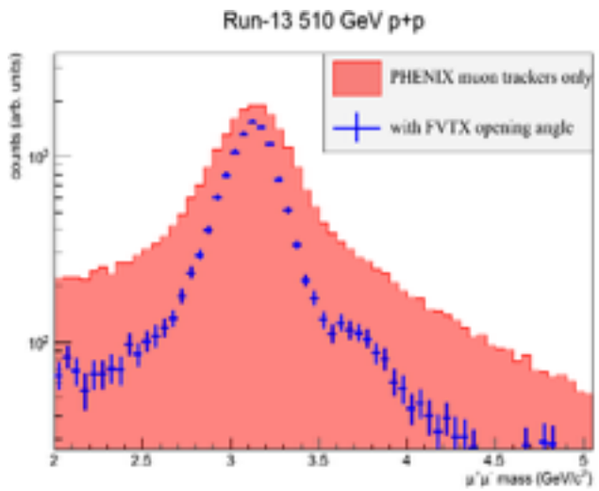
W and Drell-Yan:

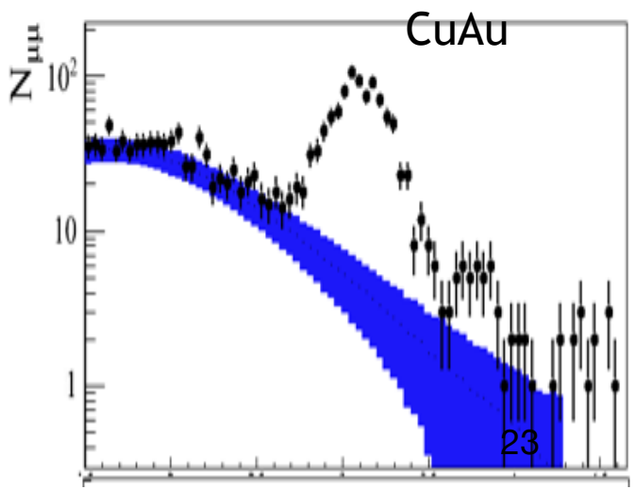
- FVTX provides unique rejections of hadronic backgrounds (track quality and isolation cuts) and heavy flavor
- Analysis in progress



First J/ψ:ψ' ratio at forward rapidity





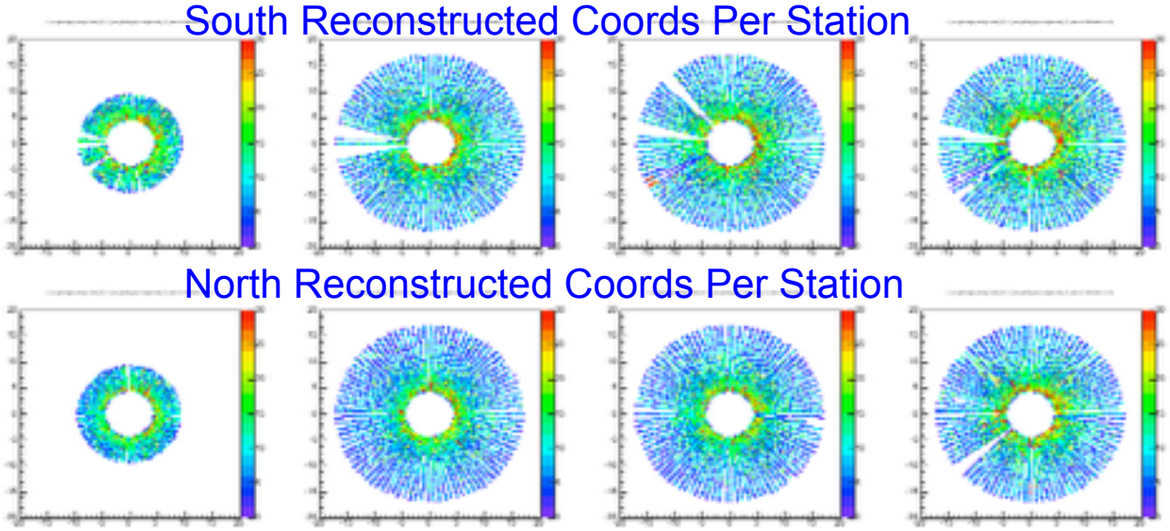


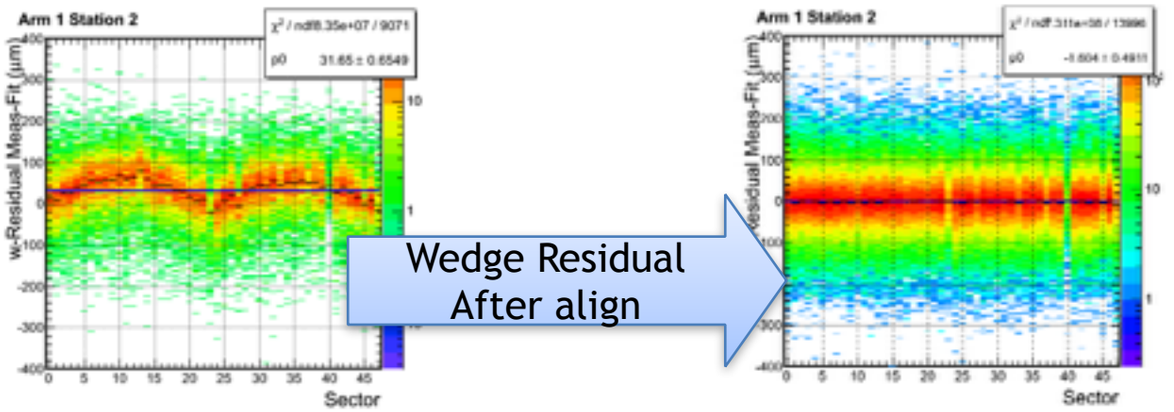
Run 14 Au+Au Performance

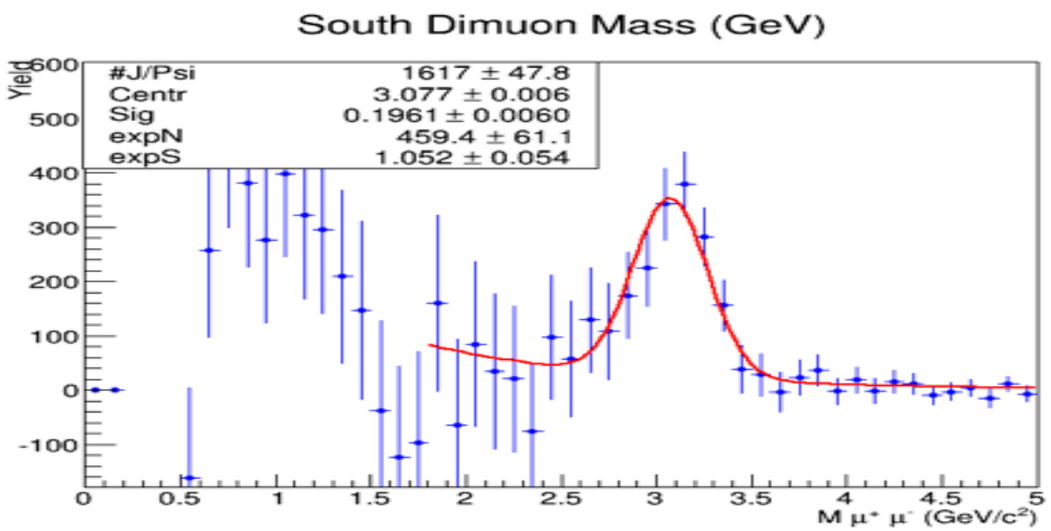
- Large fraction of FVTX detector live for Run 14 data taking.

- Detector aligned in close to real-time (early in Run 14). Few μm residuals obtained.

- Clear J/ψ peak from muon arms reconstructed online. Full data production with all detectors coming soon.







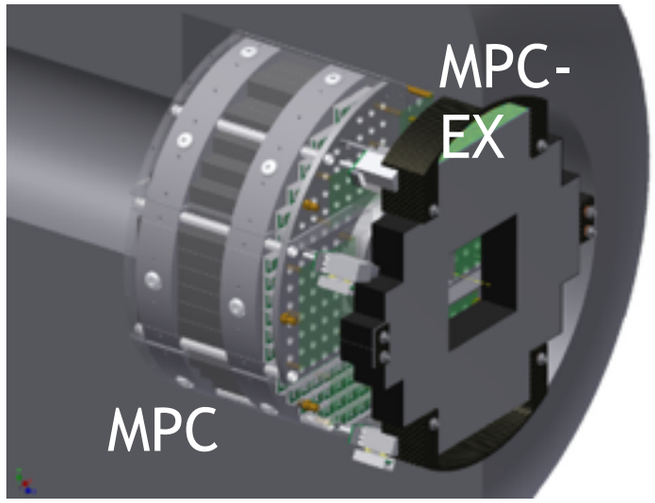
MPC-EX: The Big Questions

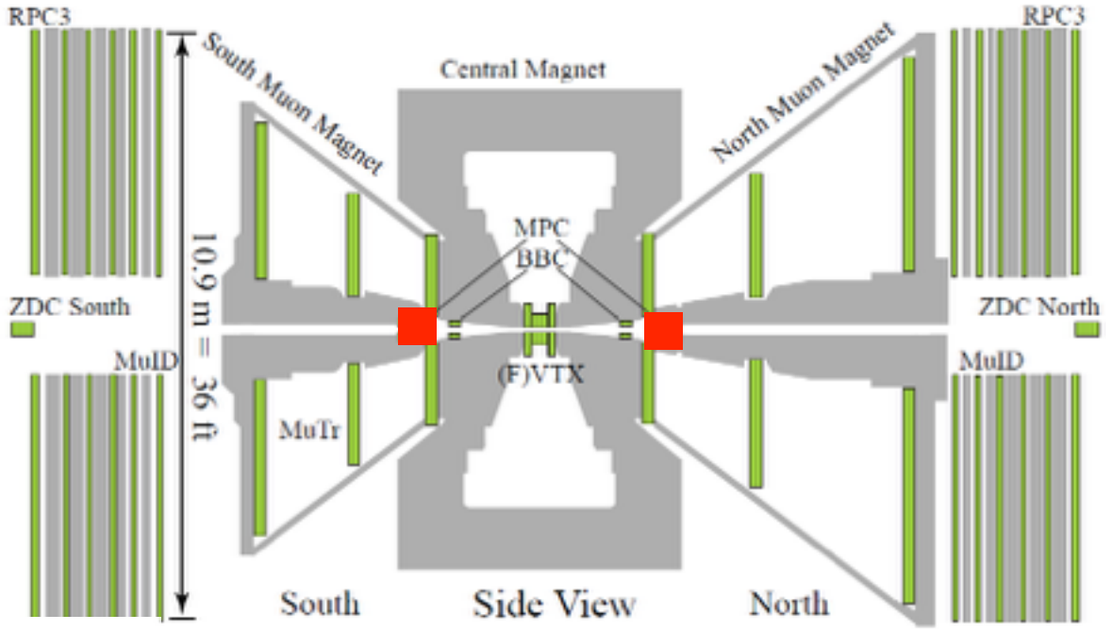
- What is the gluon density in heavy nuclei in the RHIC kinematic range?

- What role does saturation play in determining this gluon density in heavy nuclei? What is the saturation scale Q_s, and how does it depend on A and x?

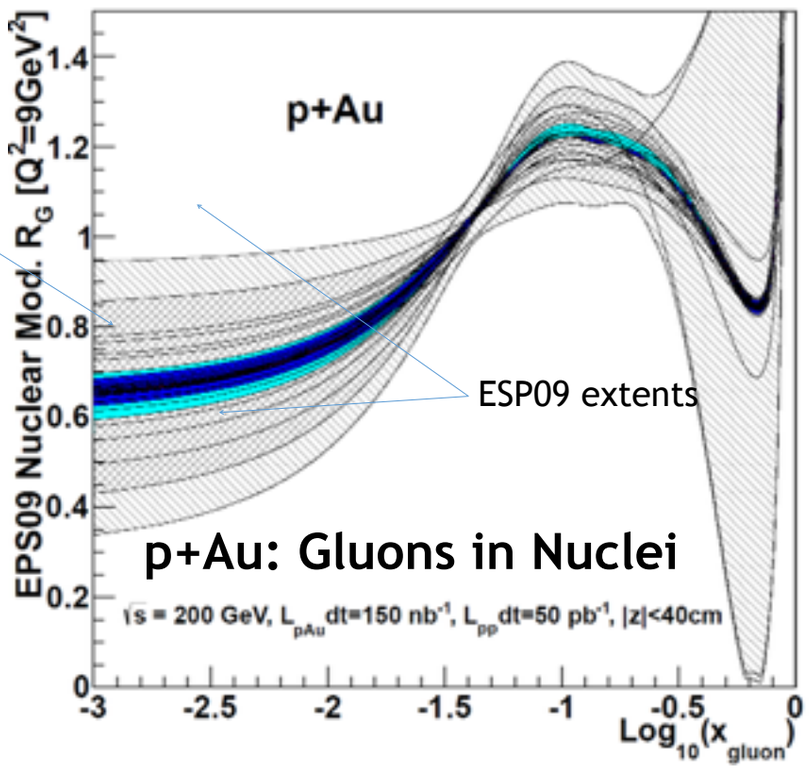
- What is the relationship between the proton spin and transverse motion of its partonic constituents?

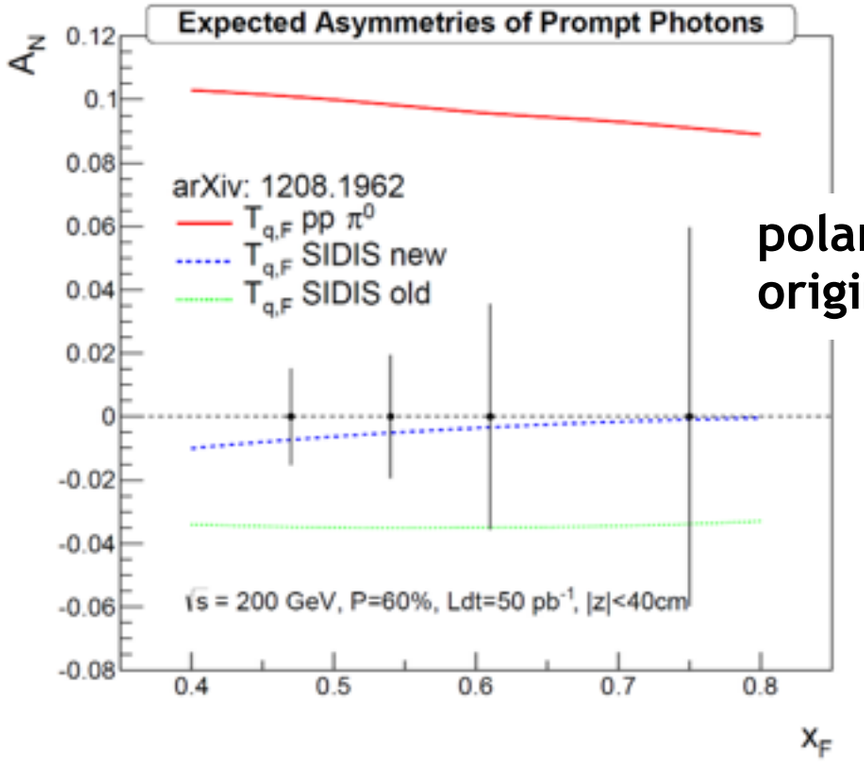
The Muon Piston Calorimeter Extension (MPC-EX)





Colored band = range with MPC-EX direct photon data





polarized p+p: origin of A_N

MPC-EX Installation

- PHENIX Installation Schedule calls for (Don Lynch):
  - MPC-EX N installation and testing 9/8-9/26
  - MPC-EX S installation and testing 10/6-10/24

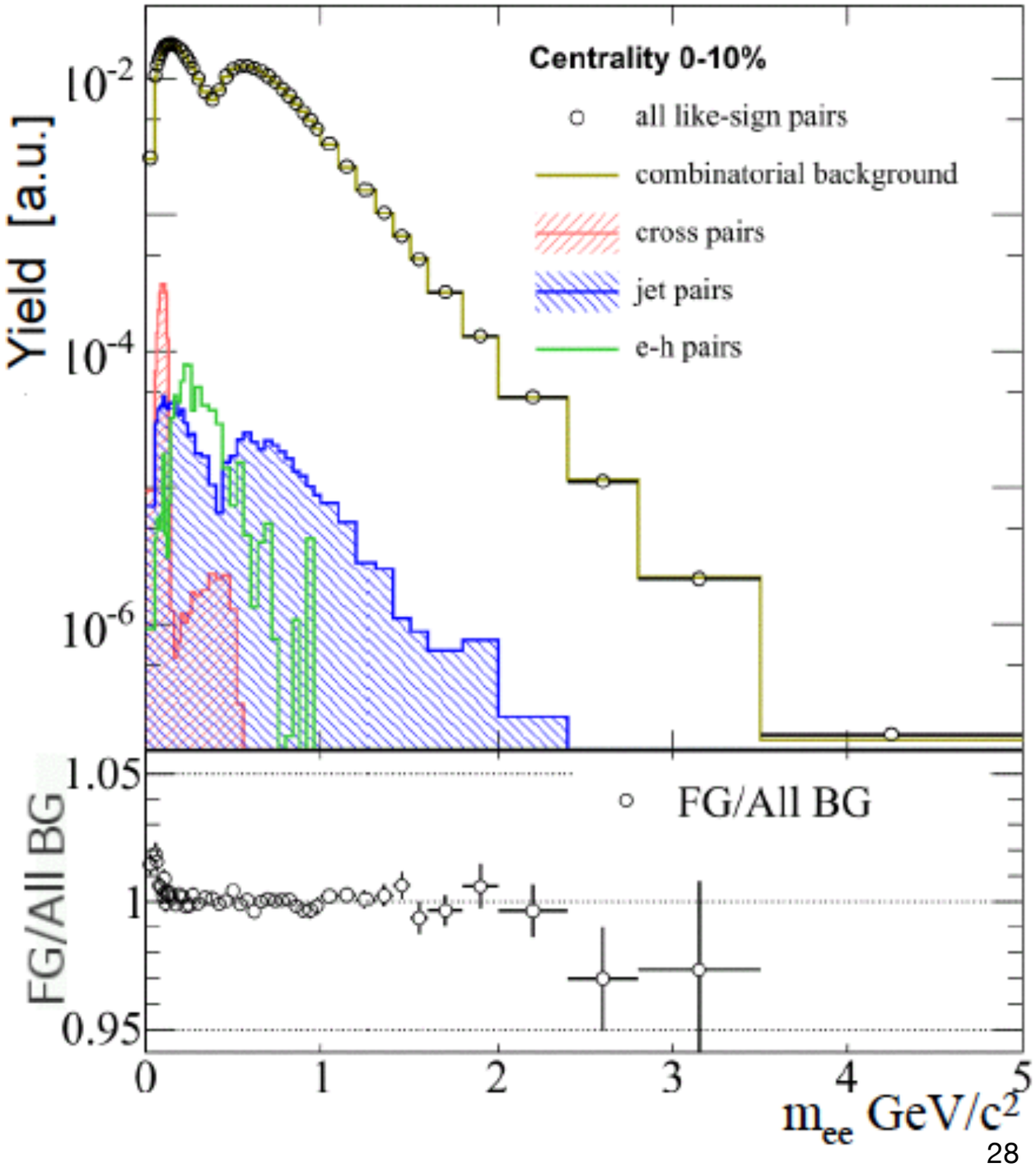
- MPC-EX Group is aiming for completion of MPC-EX N assembly by 9/15
  - Currently assembling each layer at SB, cosmics test ~1 day, assemble next layer and test again,…

- Exact date of completion of MPC-EX S depends on ROC delivery, expect to be able to meet PHENIX installation window

- MPC-EX group committed to the goal of 100% live channels…

Low-mass dileptons: HBD analysis central collisions 0-10%

- Two groups (Wiezmann, SBU) have conducted independent (though coordinated) analyses. SBU analysis is a “blind” analysis – due to be “unblinded” soon.
- Quantitative understanding of the background verified by the like-sign spectra.
- Combinatorial background determined using the mixed event technique and taking into account flow.
- Correlated components (cross pairs, jet pairs and e-h pairs) independently simulated and absolutely normalized.
- Background shape reproduced at sub-percent level for masses $m > 150$ MeV/c^2



Physics in addition to dielectrons enabled by the HBD

- Used to reject backgrounds for high p_T charged tracks, electron ID
- Double Spin Asymmetry of Electrons from Heavy Flavor Decays in *p+p* Collisions at $\sqrt{s}$ = 200 GeV
  Phys. Rev. D 87, 012011 (2013)
- Constraining gluon polarization contribution to the proton spin with high p_T charged pion production in *p+p* collisions at $\sqrt{s}$ = 200 GeV
  arXiv:1409.1907 (submitted to Phys. Rev. D)
- Heavy quark production and elliptic flow in Au+Au collisions at $\sqrt{s_{NN}}$ = 62.4 GeV
  arXiv:1405.3301 (submitted to Phys. Rev. C)

Run-15/16 BUP

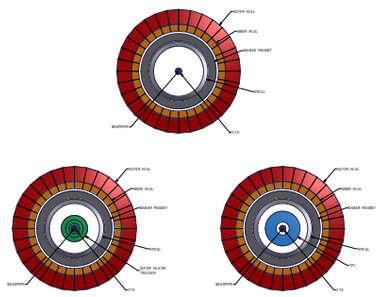
PHENIX Beam Use Proposal
Run-15 and Run-16

Submitted May 29, 2014

BES II WP

Beam Energy Scan II (2018–2019)

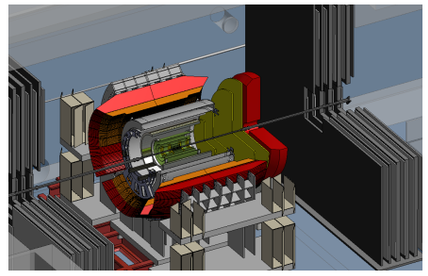
PHENIX Collaboration White Paper



Version 1: March 1, 2014

p+p/p+A WP

Future Opportunities in $p+p$ and $p+$A Collisions at RHIC with the Forward sPHENIX Detector



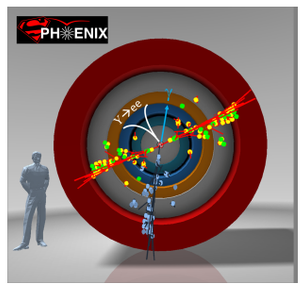
The PHENIX Collaboration
April 29, 2014

sPHENIX MIE

PHENIX

An Upgrade Proposal from the PHENIX Collaboration

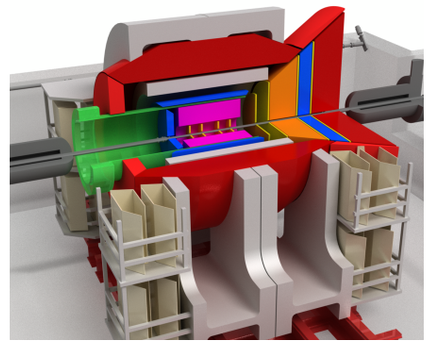
Original: July 1, 2012
Updated: October 1, 2013
Updated: June 19, 2014



arXiv:1207.6378

EIC detector concept

Concept for an Electron Ion Collider (EIC) detector built around the BaBar solenoid



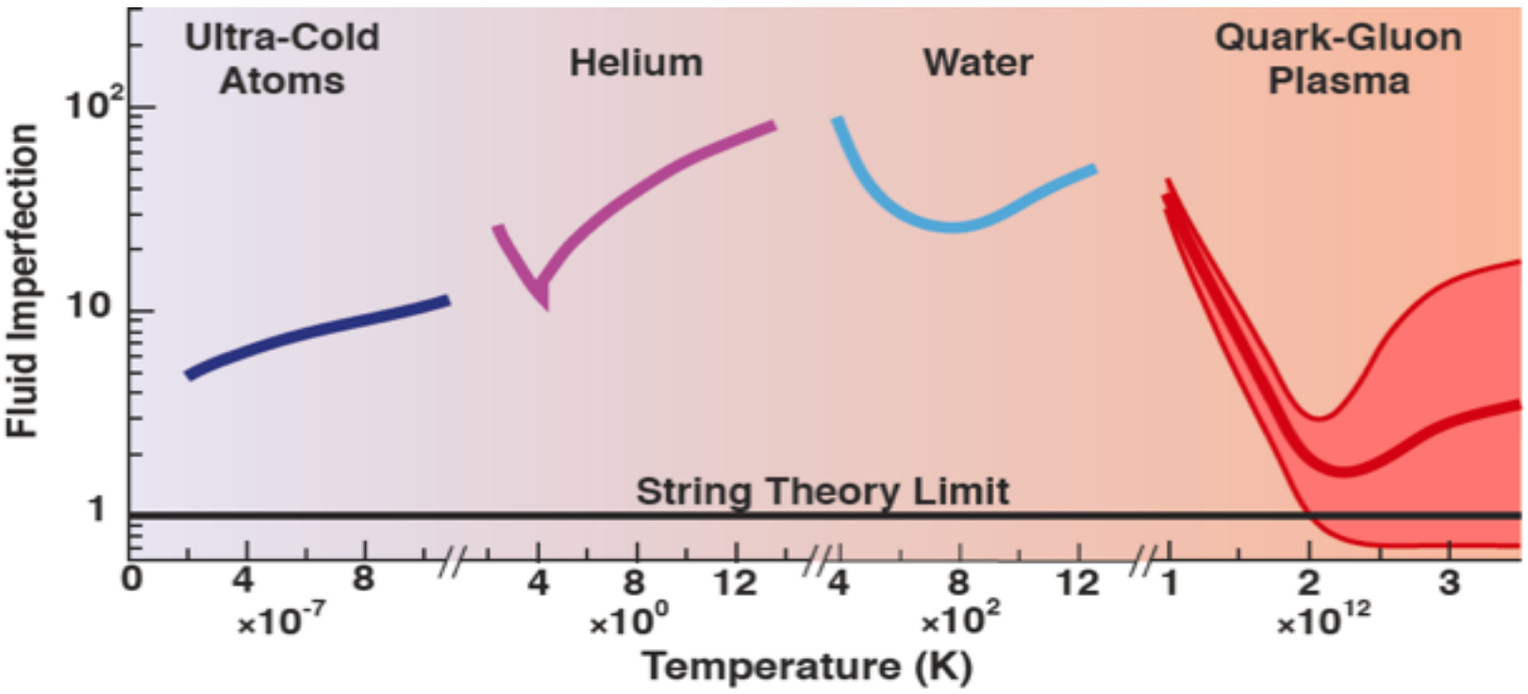
The PHENIX Collaboration
February 3, 2014

arXiv:1402.1209

Emergent Phenomena

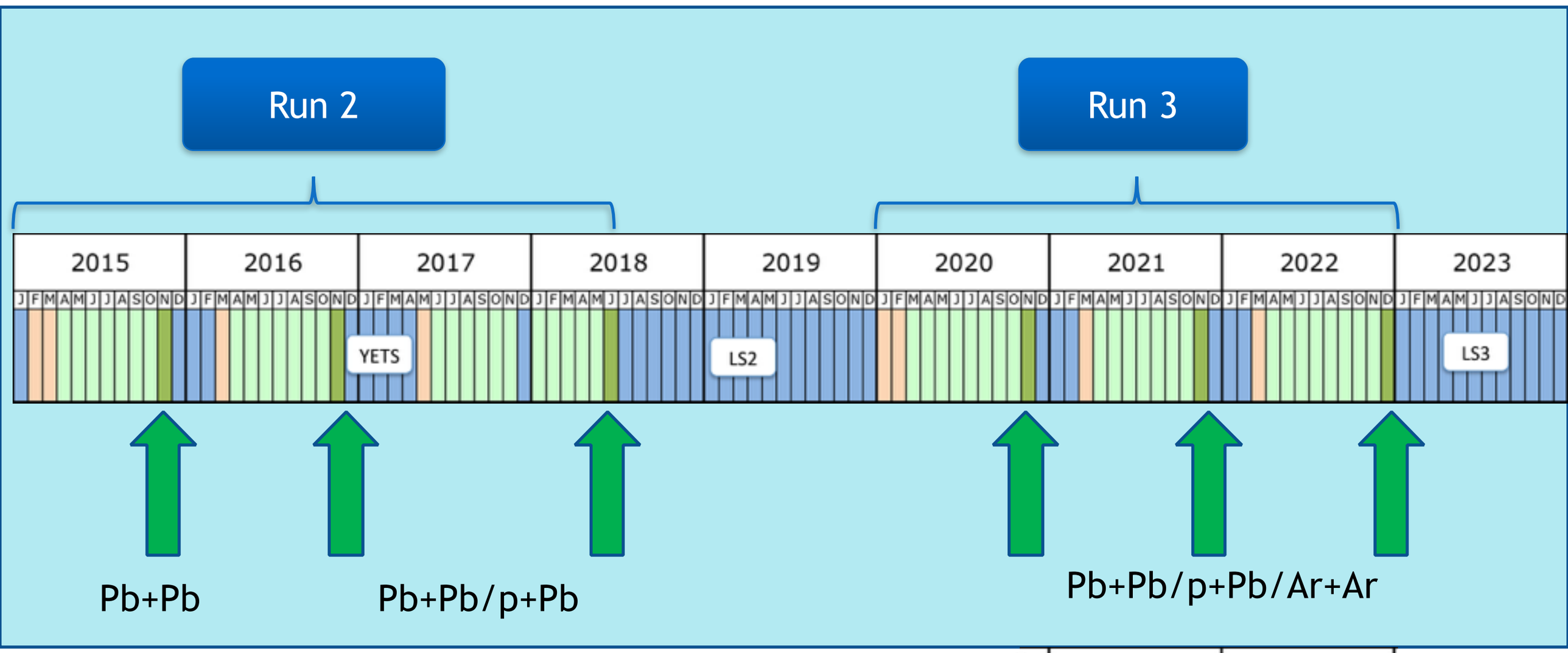
Connection from the QCD Lagrangian to phenomena of confinement and asymptotic freedom was fundamental

Connection from QCD to the emergent phenomena of near perfect fluidity of the Quark-Gluon Plasma near the phase transformation is just as fundamental



Pinning down the fluid imperfection (η/s) tells us the nature of the QGP, while leaving open the "how" and "why" questions

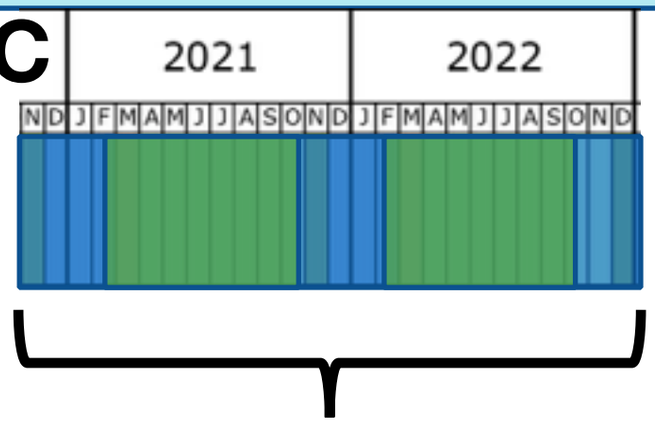
LHC Physics in the Next Ten Years



sPHENIX measurements well timed with LHC Run-3 measurements

Very good for enabling theory focus on simultaneous understanding

RHIC



PHENIX

sPHENIX Project

sPHENIX Science DOE Review took place on July 1-2, 2014

Very encouraging outcome.
Specific advice to optimize key parts of the program (in particular the tracking).

Working towards updated MIE in early November.
Integration of physics with Long Range Plan priorities.

Ed O'Brien will talk tomorrow about many specifics of the project.

Summary

- The RHIC Runs since the last S&T review (Run-12, -13, -14) have all been very successful for PHENIX (unique systems, high luminosity, growing efficiency).

- The collaboration continues to be very productive on many fronts (e.g., record number of publications)

- The VTX and FVTX performed extremely well during Run-14 and we have groups working diligently toward publishable results.

- The MPC-EX will be installed for Run-15 and the collaboration is excited about the physics it enables

- The Collaboration has developed detailed plans for the longer term involving a radical rebuilding of the detector to focus on high p_T jets, direct photons, hadrons, upsilons, and their correlations to answer “how and why” questions of the QGP.

Papers submitted/published in last 12 months

Low mass vector mesons production at forward rapidity in p+p Collisions at $\sqrt{s}$ = 200 GeV
arXiv:1405.4260, submitted to Phys. Rev. D

Comparison of the space-time extent of the emission source in d+Au and Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV
arXiv:1404.5291, submitted to Phys. Rev. Lett.

Nuclear matter effects on J/psi production in asymmetric Cu+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV
arXiv:1404.1873, submitted to Phys. Rev. C

Centrality dependence of thermal photon production in $\sqrt{s_{NN}}$ = 200 GeV Au+Au collisions
arXiv:1405.3940, submitted to Phys. Rev. C

Measurements of long-range angular correlation and quadrupole anisotropy of pions and (anti)protons in central d+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV
arXiv:1404.7461, submitted to Phys. Rev. Lett.

PHENIX centrality categorization in d+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV
arXiv:1310.4793, submitted to Phys. Rev. C

Inclusive double-helicity asymmetries in neutral pion and eta meson production in p+p Collisions at $\sqrt{s}$ = 200 GeV
Phys. Rev. D 90, 012007 (2014)

The cross-section for $b\bar{b}$ production via dielectrons in d+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV
arXiv:1405.4004, submitted to Phys. Rev. C

Heavy Quark Production and Elliptic Flow in Au+Au Collisions at $\sqrt{s_{NN}}$ = 62.4 GeV
arXiv:1405.3301, submitted to Phys. Rev. C

Cold nuclear matter effects on heavy-quark production at forward and backward rapidities in d+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV
arXiv:1310.1005, submitted to Phys. Rev. C

Quadrupole anisotropy in dihadron azimuthal correlations in central d+Au collisions at √sNN = 200 GeV
Phys. Rev. Lett. 111, 212301 (2013)

Nuclear modification of ψ', χ_c and J/ψ production in d+Au collisions at √sNN = 200 GeV
Phys. Rev. Lett. 111, 202301 (2013)

Azimuthal-angle dependence of charged-pion-interferometry measurements with respect to 2nd and 3rd-order event plane in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV
arXiv:1401.7680, submitted to Phys. Rev. Lett.

Measurement of K^0_s and K^{*0} in p+p, d+Au and Cu+Cu collisions at $\sqrt{s_{NN}}$= 200 GeV
arXiv:1405.3628, submitted to Phys. Rev. C

System-size dependence of open-heavy-flavor production in nucleus-nucleus collisions at $\sqrt{s_{NN}}$ = 200 GeV
arXiv:1310.8286, submitted to Phys. Rev. C

Azimuthal-angle dependence of charged-pion-interferometry measurements with respect to 2nd and 3rd-order event plane in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV
arXiv:1401.7680, submitted to Phys. Rev. Lett.

Measurement of transverse-single-spin asymmetries for midrapidity and forward-rapidity production of hadrons in polarized p+p collisions at $\sqrt{s}$ = 200 and 62 GeV

arXiv:1312.1995, submitted to Phys. Rev. C

Heavy-flavor electron-muon correlations in p+p and d+Au collisions at $\sqrt{s}$ = 200 GeV

Phys. Rev. C 89, 034915 (2014)

Azimuthal anisotropy of π^0 and η mesons in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV

Phys. Rev. C 88, 064910 (2013)

Measurement of the Upsilon cross section in p+p and implications to the nuclear modification factor in Au+Au at $\sqrt{s}$ = 200 GeV

arXiv:1404.2246, submitted to Phys. Rev. C

Transverse-energy distributions at midrapidity in p+p, d+Au, and Au+Au collisions at $\sqrt{s_{NN}}$ = 62.4 – 200 GeV and implications for particle-production models

Phys. Rev. C 89, 044905 (2014)

Cross section and transverse single spin asymmetry of η Mesons in p↑+p collisions at $\sqrt{s}$ = 200 GeV at Forward Rapidity

arXiv:1406.3541, submitted to Phys. Rev. D

Constraining gluon polarization contribution to the proton spin with high p_T charged pion production in p+p collisions at $\sqrt{s}$ = 200 GeV

arXiv:1409.1907 (submitted to Phys. Rev. D)

Closing the door for dark photons as the explanation for the muon g-2 anomaly

arXiv:1409.0851, submitted to Science

MPC-EX Fabrication Status

- Micromodule Fabrication and Testing (BNL/SB)
  - 192 modules required per MPC-EX arm (384 total)
  - As of 8/22 a total of 321 micromodules have been assembled:
    - 222 micromodules wire bonded and tested
      - Of these 196 are “good” – good leakage current and no dead areas
      - Of remaining 26 - 8 “dead/bad”, 5 have confirmed dead areas, 9 require additional testing, 4 draw very high current at low bias voltage
    - 99 micromodules awaiting wire bonding
    - Sufficient micromodules on hand for MPC-EX N
    - Additional 100 ROCs have been ordered, sufficient parts on hand to “overproduce” to account for losses at various production stages.
      - Losses in ROC testing unexpectedly high at 24%, classifying for possible later use
- Sensor Testing and Delivery
  - Yonsei has completed total delivery of 480 sensors + (40 sensors are “2nd class” sensors, slightly higher leakage current but still acceptable)
- Carrier Boards
  - Carrier board and tungsten lamination underway (BNL)

MPC-EX Electronics

- Added Chuck Pancake (SB) and Joszef Imrek (BNL) to FEM design/ firmware
- Rev0 FEM is being used for FPGA development but not acceptable for final detector:
  - Choice of FPGA pins for LVDS not consistent with mfg. specification; some wire-mod error correction; change in design of readout cable routing and slow controls connection
  - Rev1 FEM completed and reviewed 8/23
  - Expect completion of CB readout and optical link testing ~ 1 week
- FEM P/S Board in Production
- Electronics Box Mock-Up Completed
- Remaining Elements:
  - RPi to LVDS for FEM connection (BNL)
  - Cable interconnect (L/R styles – BNL, out for production)